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WIRTANEN: A BRIGHT COMET FOR CHRISTMAS?

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Sky at Night

#163 DECEMBER 2018

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NIGHT SKY 2019

Next year's observing highlights

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Sky at Night MAGAZINE REVIEWED IN ISSUE 112 SEPTEMBER 2014 ★★★★★

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www.celestron.uk.com

This month's contributors include...

Nicholas Joannou
Equipment expert

Eyepieces may not look as impressive as scopes but Nicholas explains why they are just as vital for observing. *Page 80*

Deirdre Kelleghan
Astronomy educator

Contributing to our new regular column, Field of View, Deirdre extols the use of art to teach astronomy. *Page 23*

Stuart McIntyre
Astrophotographer

Stuart loves capturing the entire night sky in a 360° panoroma, and this issue he explains the entire process. *Pages 38 & 84*

Elizabeth Pearson
News editor

Elizabeth takes time out from writing astro news to recount the events of the first humans who orbited the Moon. *Page 102*

Welcome

Make the most of a Moonless Geminid meteor shower

This month the Geminid meteor shower makes a return to our night skies. It's a particularly good year to observe them as the crescent Moon cooperates by setting before 10pm, so there'll be a nice, dark sky against which even faint meteor trains should stand out. There are full observing details in the Sky Guide on page 53, and the lowdown on recording your meteor observations for the scientific record on page 82. It's worth noting that next year's display will feature a gibbous Moon in Gemini itself, so make the most of this year!

But as you'll find out in our feature on page 32 about 2019's observing highlights, there's much more to look forward to in the night sky over the next 12 months. This issue we also have a fascinating look at creating 360° night-sky panoramas; discover how to capture them on page 38 and how to process those captures on page 84. And with Christmas around the corner our reviews from page 89 focus on equipment that would make an ideal gift for beginners. Let's hope Comet Wirtanen is on view for their first observations – see page 52 for the prospects!

Enjoy the issue,

Chris Bramley Editor

PS Our next issue goes on sale 20 December.

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The more we know about what you like, the better placed we are to bring you the best magazine possible. So we'd like to invite you to join our online reader panel 'Insiders'. Just log on to **www.immediateinsiders.com/register** to fill out the short registration survey and we'll be in touch from time to time to ask for your opinions on the magazine and other relevant issues.

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Get started with The Guide on page 80 and our online glossary at www.skyatnightmagazine.com/dictionary

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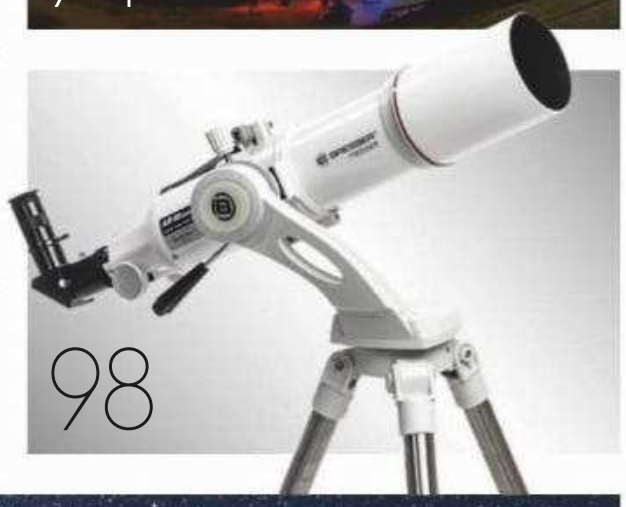
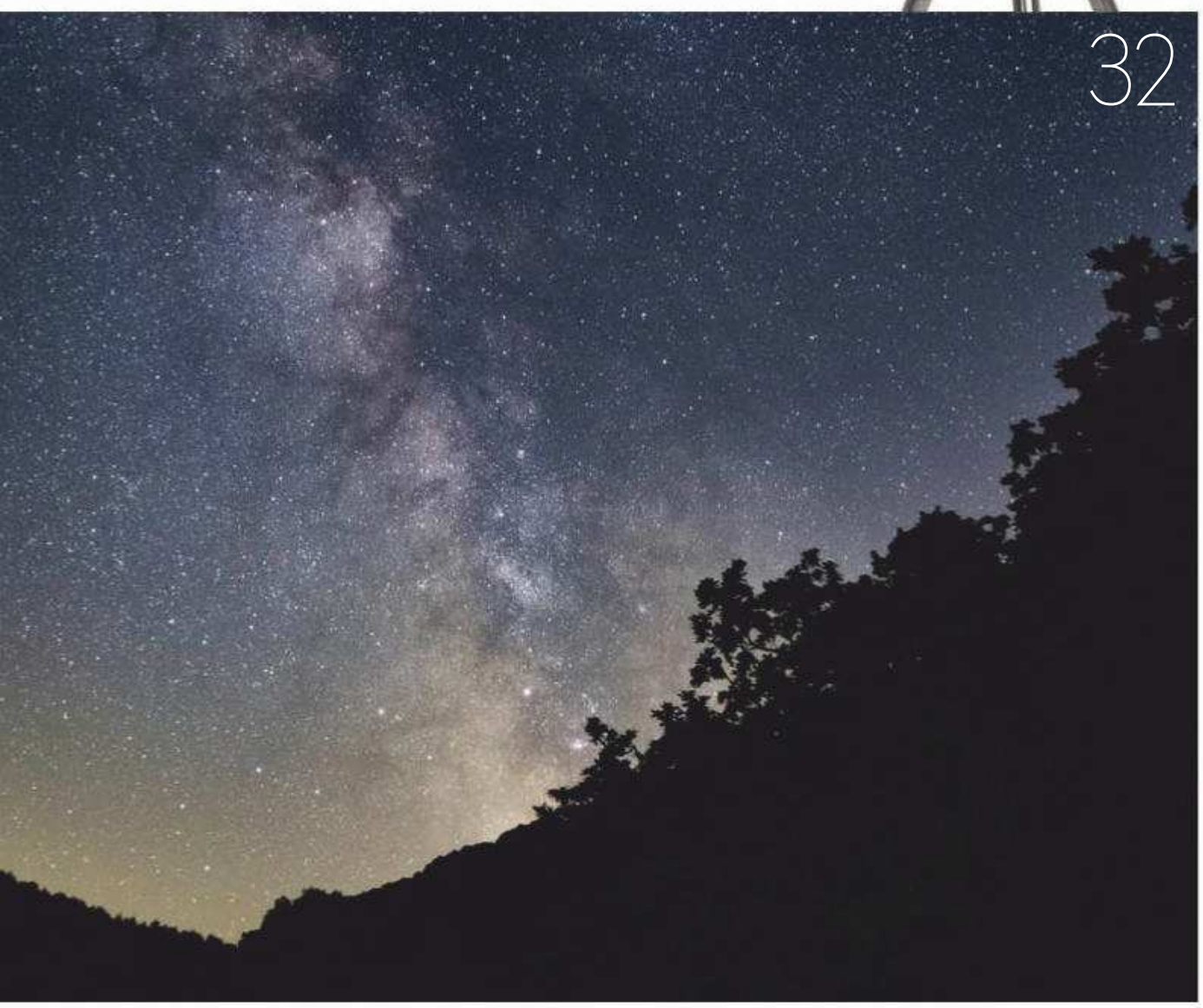




Regulars

DECEMBER'S BONUS CONTENT

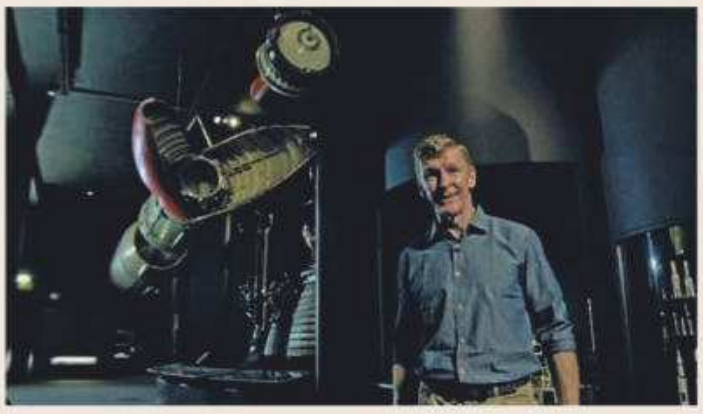
HOW TO FIND IT

Visit **www.skyatnightmagazine.com/bonuscontent**, select December's Bonus Content from the list and enter the authorisation code **BJ97HYS** when prompted

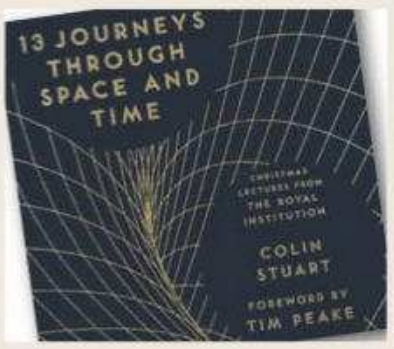
THERE'S MORE ONLINE

December highlights

Watch *The Sky at Night*



British astronaut Tim Peake joins *The Sky at Night* team as a guest presenter in an episode that looks at the history of British spaceflight and the current plans to build the UK's first space port on the A'Mhoine peninsula in Sutherland, Scotland. Also, Pete Lawrence reveals how to catch the flare of an Iridium satellite in the night sky.



A guide to Sagan's Christmas Lecture

Listen to a chapter from *13 Journeys Through Space and Time* about Carl Sagan's 1977 Royal Institution talk.

Moons beyond the Solar System?

Watch our interview with Prof David Kipping, part of a team that may have just discovered the first known exomoon.

Download and listen: *It Is Rocket Science*

Enjoy the first episode of Helen Keen's popular BBC Radio 4 comedy series on the science of spaceflight.

And much more...

- ▷ **Hotshots gallery**
- ▷ **Eye on the sky**
- ▷ **Extra EQMOD files**
- ▷ **Binocular tour**
- ▷ **Equipment review guide**
- ▷ **Desktop wallpaper**
- ▷ **Observing forms**
- ▷ **Deep-sky tour chart**

EVERY MONTH
Virtual Planetarium
With Paul Abel and Pete Lawrence
Discover December's night-sky highlights with Paul and Pete

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Behemoth of the young Universe

A glimpse back in time to the dawn of the Universe reveals a massive proto-supercluster that could give us clues about how our own Virgo supercluster evolved

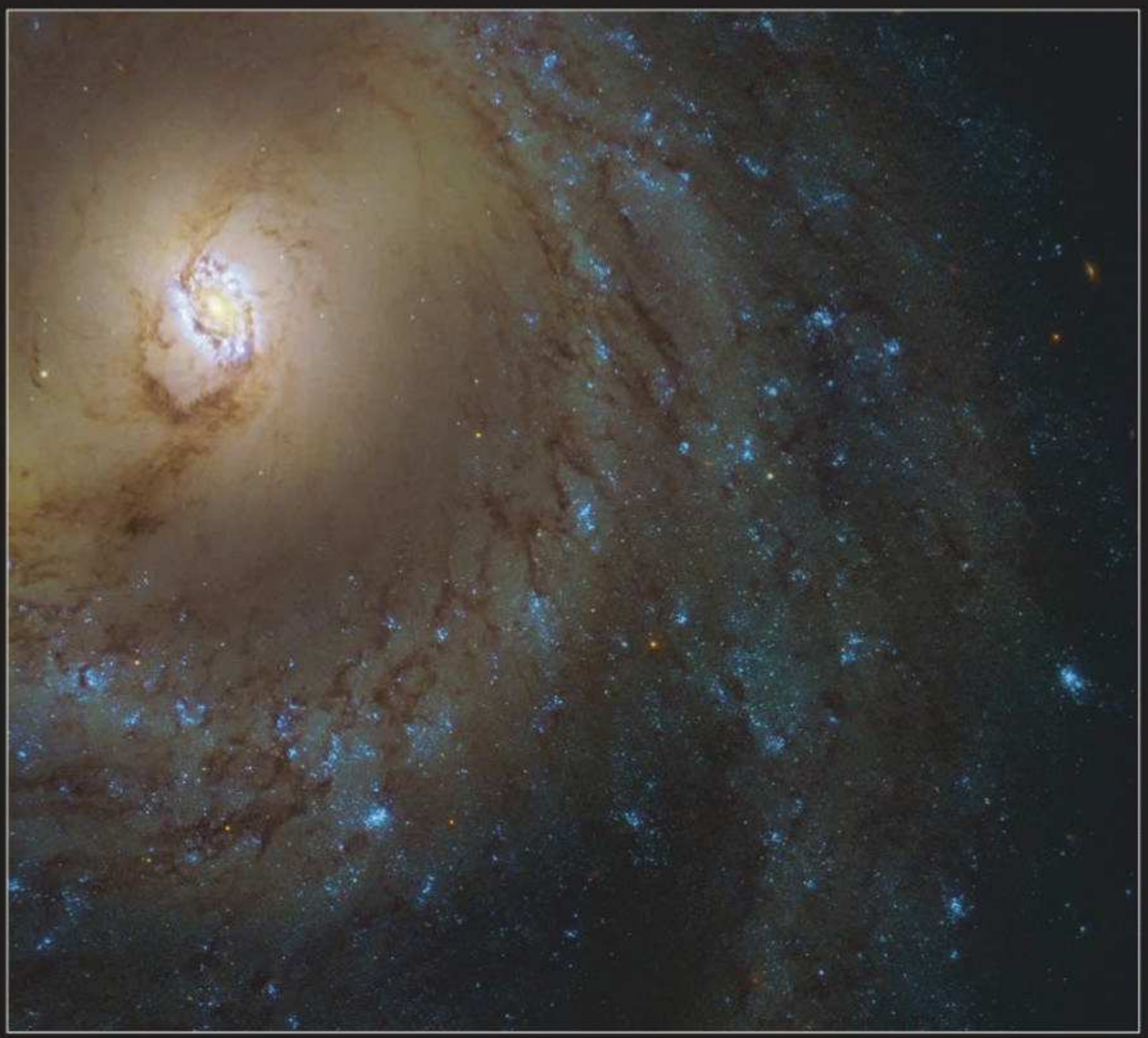
VERY LARGE TELESCOPE, 17 OCTOBER 2018

Because light takes time to travel across space, astronomers can effectively look back in time by observing ever deeper into the cosmos to see objects as they existed in the Universe's infancy. Hyperion – the object seen here – appears as it did about 12 billion years ago, two billion years after the Big Bang.

This object is known as a galaxy proto-supercluster and is the largest and most massive structure ever observed so distant and early in the history of the Universe. It consists of galaxies held together in a cluster, forming an object whose mass is equal to over one million billion times that of our Sun.

It is thought that Hyperion will eventually evolve into something like the Virgo Supercluster in which our own Galaxy is found, so studying this object and comparing it with others closer to us in the local Universe can reveal clues as to how the cosmos formed and evolved over time.

ESO/L. CALÇADA & OLGA CUCCIATI ET AL.



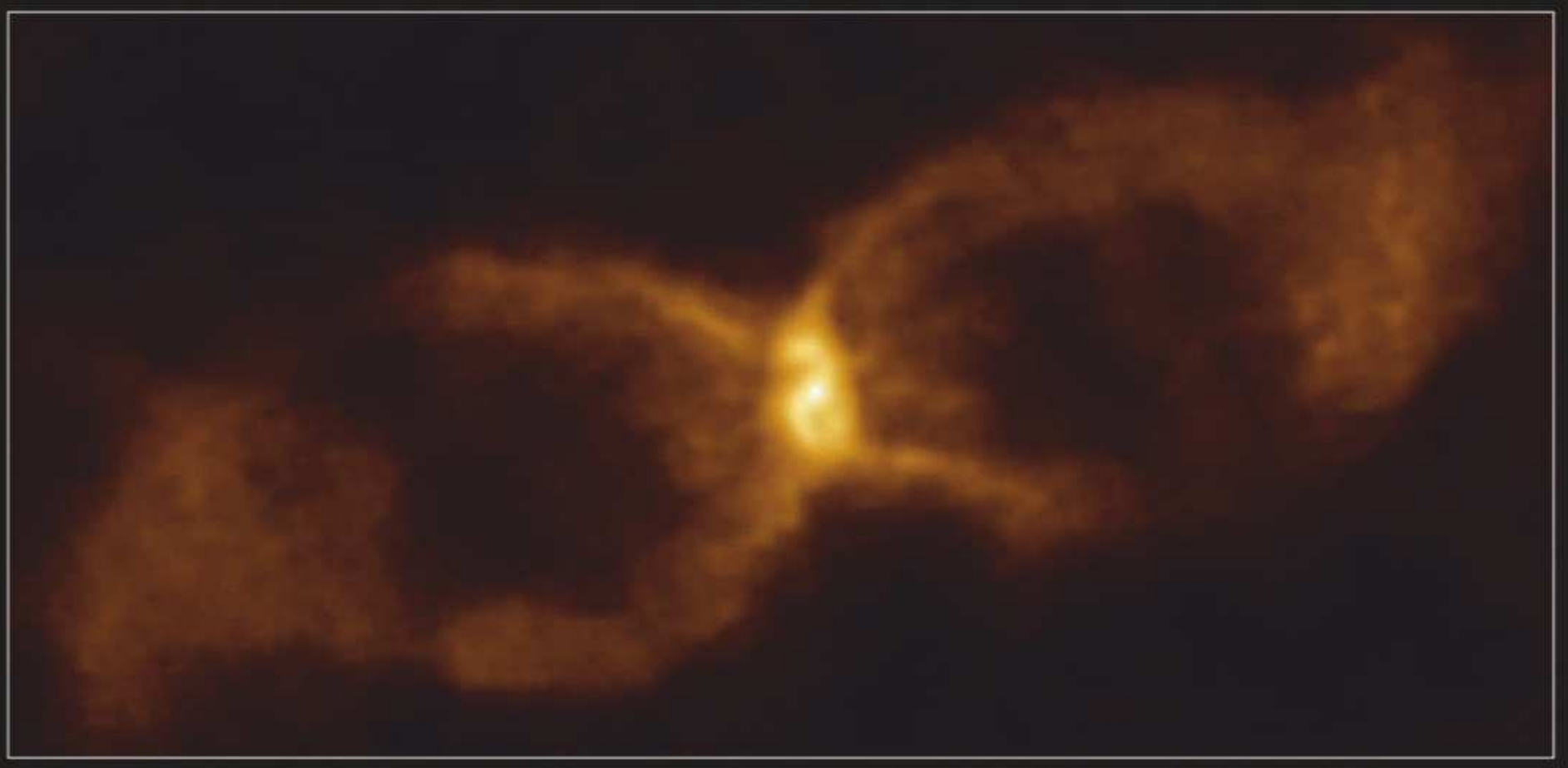
◀ Ring within a ring

HUBBLE SPACE TELESCOPE, 8 OCTOBER 2018

Young stars glow bright in the arms of spiral galaxy Messier 95. If you look towards the bright centre of the galaxy, you'll see a smaller inner ring surrounding the galactic core. This is another star-forming region, fed by the wisps of dark dust spiralling inwards.

YOUR BONUS CONTENT

A gallery of these and more stunning space images



▲ The reappearing remnant

ATACAMA LARGE MILLIMETER/SUBMILLIMETRE ARRAY, 8 OCTOBER 2018

CK Vulpeculae was first spotted in 1670, a visible object in the night sky that changed in brightness before disappearing and reappearing twice, then finally vanishing from naked-eye view. Modern telescopes have confirmed it to be the remnant of two colliding stars, but it is still not known exactly what kind of stars were involved.

ESA/HUBBLE & NASA, ALMA (ESO/NAOJ/NRAO)/S. P. S. EYRES, NASA/JPL-CALTECH, SOLAR DYNAMICS OBSERVATORY/NASA

▲ Glimpse of the Cat's Paw

SPITZER SPACE TELESCOPE, 23 OCTOBER 2018

The Galactic Legacy Infrared Midplane Survey Extraordinaire (GLIMPSE) is a survey of the Milky Way Galaxy using Spitzer, and this incredible image is just one of many produced as part of the mission. It shows the Cat's Paw Nebula, a stellar nursery 5,500 lightyears away, revealing its glowing clouds and black filaments of dense gas and dust, which may one day collapse in on themselves precipitating the formation of new stars.

Solar slow-down

NASA SOLAR DYNAMICS OBSERVATORY, 10 OCTOBER 2018

A new active region spins into view in this image of the Sun captured by NASA's orbiting observatory. Such regions are becoming rarer as the Sun approaches the solar minimum; the point in our host star's 11-year solar cycle when its activity slows down.

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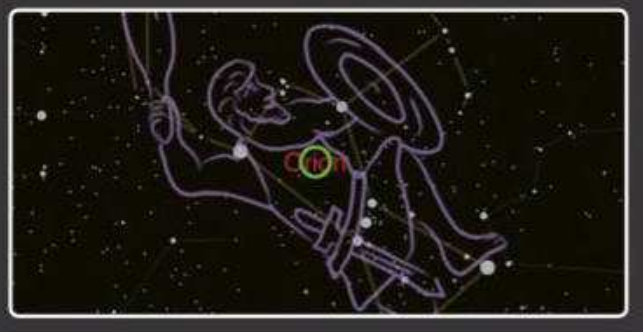

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Bulletin

The latest astronomy and space news written by **Elizabeth Pearson**

PLUS CUTTING EDGE

Our experts examine the hottest new astronomy research papers

Scientists believe they have discovered the first moon outside our Solar System around Kepler-1625b

NASA/ESA/L. HUSTAK

Moon found beyond the SOLAR SYSTEM

Exoplanet appears to have an unusually large satellite

New observations have found evidence of a moon the size of Neptune in orbit around an exoplanet. If confirmed, this will be the first time a moon has been discovered outside our Solar System.

The Kepler Space Telescope found the first signs of a moon in orbit around the 8,000 lightyears-distant exoplanet Kepler-1625b in 2017. A team of scientists investigated further using the Hubble Space Telescope, looking for dips in the host star's brightness that could have been caused by the planet and moon passing in front of it. After first detecting the main planet's transit, Hubble then spotted a second dip in brightness 3.5 hours later.

"A companion moon is the simplest and most natural explanation for the second dip," said David Kipping, from Columbia University, who took part in the study. "It was definitely a shocking moment to see that light curve."

The team also noted the planet's transit occurred an hour earlier than expected. The presence of a moon could cause this, as it would pull the centre of gravity away from the core of the planet, causing it to wobble.

A second planet could be responsible for both these observations, but during Kepler's four-year run it found no evidence of an additional planet around Kepler-1625.

The find will hopefully, "yield new insights into the development of planetary systems and may cause astronomers to revisit theories of how moons form," according to Alex Teachey, the Columbia University graduate student who led the observations.

▸ **See Comment, right**

COMMENT

by Chris Lintott

Can we really call this new object a moon? Something the size of Neptune certainly doesn't look like any satellite in our Solar System.

In fact, the relative masses of this new exomoon and its planet are about the same as the difference between Earth and the Moon. Granted, our Moon is unusually large – large enough that in the absence of official rules as to what qualifies as a moon some argue we really inhabit a double planet system. But knowing this makes the new system seem more familiar.

Even if that's true, though, those who study planet formation have a struggle on their hands to explain how two such large bodies could have ended up in orbit around one another.

And things might be more complicated still; astronomers have pointed out that there's the possibility of satellites in orbit around this new body too. Delightfully, these would be known as 'moonmoons'.

CHRIS LINTOTT co-presents *The Sky at Night*

NEWS IN BRIEF

BEPICOLOMBO LAUNCHES

ESA's Mercury mission, BepiColombo, successfully launched on 20 October at 01:45 UT, starting its seven-year journey to the innermost planet. The mission consists of two spacecraft – one from Europe, the other from Japan – that will orbit the planet, observing its geology and composition. Researchers hope the mission will help to answer the many questions surrounding Mercury, such as why it has a magnetic field when some larger planets don't.

PLANET GOBLIN REVEALED

The discovery of a new dwarf planet – nicknamed 'the Goblin' – was announced in October by astronomers hunting for a ninth large planet on the outskirts of our Solar System. The Goblin is currently 2.5 times further from the Sun than Pluto, and its orbit seems to have been shaped by the theoretical ninth planet. "These distant objects are like bread crumbs leading us to Planet X," says Scott Sheppard from Carnegie Institution for Science, who led the study.

Astronomers are scratching their heads as to why hypervelocity stars are racing towards the Galactic core

Stars hop BETWEEN GALAXIES

Stellar interlopers could be speeding towards us at huge velocity

A group of astronomers looking for stars escaping the Milky Way could instead have found several invading it from another galaxy.

The team made the discovery during a recent analysis of data from the Gaia spacecraft. Since 2014, Gaia has measured the positions, parallaxes (a measure of distance) and 2D proper motion on the sky of over a billion stars. Seven million of these stars have full 3D data, meaning it's possible to work out how quickly they are moving towards or away from us.

A team of researchers from Leiden University in the Netherlands used this 3D data to search for hypervelocity stars. These are stars that have been accelerated to phenomenal speeds, probably through interactions with a supermassive black hole.

"Of the seven million Gaia stars with full 3D velocity measurements, we found 20 that could be travelling fast enough to eventually escape the Milky Way," says Elena Maria Rossi, one of the researchers involved in the study.

Based on a previous look at the Gaia data, the team expected to find perhaps one hypervelocity star breaking loose from the Galaxy, so were pleasantly surprised when so many turned up. More unexpected was the direction in which the stars were travelling.

"Rather than flying away from the Galactic centre, most of the high velocity stars we spotted seem to be racing towards it," says Tommaso Marchetti, who took part in the research. "These could be from another galaxy, zooming right through the Milky Way."

The stars may have originated in the Large Magellanic Cloud or they could come from much further afield. Astronomers will now study the stars to see if they can determine their origin. If they do turn out to be intergalactic interlopers, the stars could offer researchers a unique opportunity to take a detailed look at stars from another galaxy.

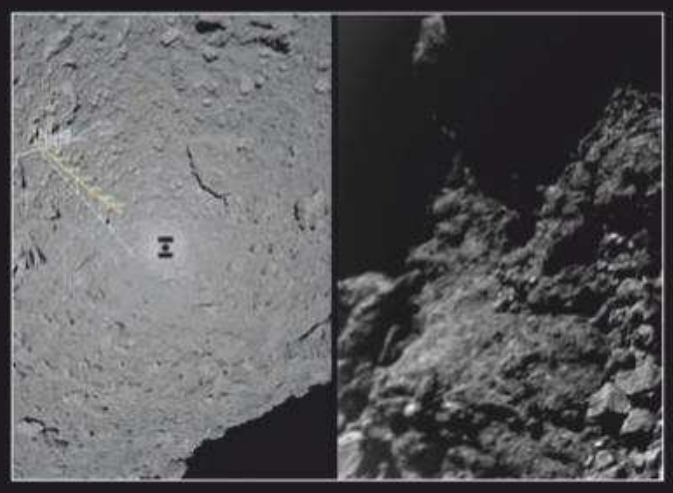
"Looking at the colours of the stars tells us what they are made of," says Marchetti. "A star from the Milky Way halo is likely to be fairly old and mostly hydrogen, whereas stars from other galaxies could contain lots of heavier elements."

sci.esa.int/gaia

Lander dropped onto asteroid

Hayabusa2 dropped its third and final lander onto asteroid Ryugu on 3 October. The MASCOT probe, created by Germany's space agency, explored the surface for over 17 hours. It was controlled directly from Earth throughout, the first time a lander has been operated in this way.

It took MASCOT six minutes to reach the surface, where it bounced eight times before coming to rest. It then used a robot arm to manoeuvre itself into the best position to conduct its experiments. The lander spent two asteroid days and nights observing its landing location, then used its arm to 'hop' to another area and continued taking measurements until its battery ran down. The images revealed a surface strewn with boulders, but without the fine material scientists were expecting to see.



▲ The MASCOT team was surprised that the surface of Ryugu isn't covered in fine material as expected

"MASCOT has delivered exactly what we expected: an 'extension' of the space probe on the surface of Ryugu and direct measurements on site," says Tra-Mi Ho, the MASCOT project leader.
www.dlr.de

Launch to ISS aborted

The two astronauts made an emergency landing but were unharmed

Two astronauts were forced to abort their flight to the International Space Station (ISS) on 11 October. An anomaly occurred when the rocket booster was due to separate from the spacecraft, triggering a safety warning. The crew capsule automatically fired its engines, carrying NASA astronaut Nick Hague and cosmonaut Alexey Ovchinin, to safety.

The event closely follows an incident in September, when a hole was found in the hull of a Soyuz spacecraft while it was docked with the ISS. The Russian space agency Roscosmos has put crewed launches on hiatus until they uncover the exact cause of the issue.

If launches haven't resumed by December 2018, when the current crew will be forced to return to Earth for safety reasons, the station could be left uncrewed for the first time since 31 October 2000.
en.roscosmos.ru

▲ Alexey Ovchinin, left, and Nick Hague embrace their families at Krayniy airport after a flight to the ISS was aborted

NEWS IN **BRIEF**

BIG BANG WAS FLUID

The latest experiments at CERN's Large Hadron Collider (LHC) show that the early Universe may have behaved like a fluid. By smashing particles together at close to the speed of light, the LHC recreates the plasma of quarks and gluons – the particles that make up protons and neutrons – that filled the Universe just after the Big Bang. These tests found that the plasma follows the same physical laws as fluids. Researchers will continue to examine the plasma to learn more about its properties.

NEARLY A NOVA

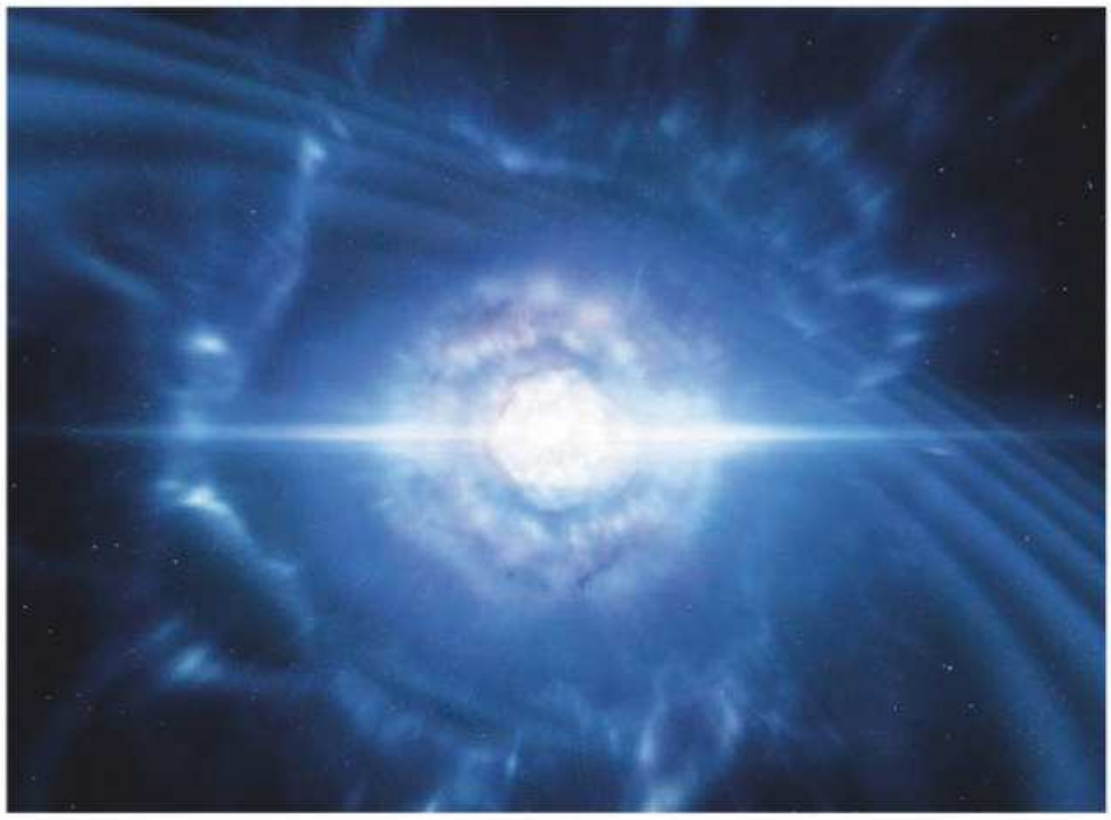
A pair of binary stars that orbit each other in just three hours has been discovered in the heart of a planetary nebula using new observations from the European Southern Observatory. The pair is so close they are almost touching. Their proximity means within the next thousand years they could undergo a nova eruption, where material from one star rapidly transfers over to the other. The resulting thermonuclear explosion creates a burst of light a million times brighter than the original stars.

CUTTING EDGE

Our experts examine the hottest new research

Fine-tuning multi-messenger astronomy

A new experiment hopes to hone the links between gravitational wave and gamma ray detectors



ESO/L. CALÇADA/M. KORNMESSER

▲ **Combined data from Fermi and LIGO appears to confirm a gamma-ray burst that would look ambiguous based on the data from just one source**

When the 2017 Nobel Prize was awarded for the detection of gravitational waves, it marked the end of an incredible story. Through 30 years of finding absolutely nothing, the team behind the LIGO project had worked on and on, building more and more sensitive experiments until they finally detected the minuscule ripples in space caused by the collision of two black holes in a distant galaxy.

This first detection by the LIGO experiment was quickly followed by another, and another, and finally the spectacular discovery last year of gravitational waves from a gamma-ray burst that was also seen by telescopes in space and around the world. That event, with gravitational wave and 'traditional' astronomers working together, is a whole new way of doing astronomy.

It's one we don't really understand how best to use yet, but we need to get ready fast. Since these initial discoveries, the LIGO team has been upgrading its detector to make it even more sensitive. The team has also promised that when it restarts next year, it will share the stream of alerts that signal possible detections with the world. A new paper by an enormous number of scientists (there are three whole pages which just contain the names of the authors) shows how this might work.

Rather than wait for the new data, the team used NASA's Fermi satellite to hunt for signals that happened to coincide with activity detected by LIGO. Fermi looks at the whole sky, keeping an eye out for gamma-ray bursts. It was this capacity that enabled it to be the first to pick up on the gamma-ray burst that LIGO detected. Rather than just looking at Fermi data at the times when the gravitational wave experiments unambiguously saw something, the team looked for bursts that accompanied times when LIGO seems to have seen something, but where the signal wasn't strong enough to confirm a detection.

There were about a thousand of these 'nearly' events; some will undoubtedly have been random fluctuations, but others may well have been real. They could be distant events, or events associated with less powerful gravitational wave emitters. Looking for matches in the Fermi data for each of these events found... almost none.

> "There was one event the LIGO team had suggested could be real that seems also to have been faintly detected by Fermi"

But there was one event the LIGO team had suggested could be real (known as GW150914-GBM) that seems also to have been faintly detected by Fermi. Because two separate experiments have seen hints of the same thing, we can be more confident that it's real than we would if we listened only to Fermi or only to LIGO.

That's really exciting. While the experiment didn't turn up dozens of new detections, it did help in confirming one that was previously dubious. As we enter the new era of public announcements of LIGO detections, we'll be able to use techniques like those in this paper to combine results from multiple observatories. Together, they'll tell us everything we could possibly want to know about the most dramatic and violent events in our Universe's history.

CHRIS LINTOTT is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project

CHRIS LINTOTT was reading… *A Fermi Gamma-ray Burst Monitor Search for Electromagnetic Signals Coincident with Gravitational-Wave Candidates in Advanced LIGO's First Observing Run* by the Fermi Gamma-ray Monitor Team, the LIGO Scientific Collaboration and the Virgo Collaboration.
Read it online at arxiv.org/abs/1810.02764

Our Galaxy's black hole seen flaring

The three eruptions are more evidence of Sag A*'s supermassive status

▲ **The flares around Sag A*'s event horizon were a chance discovery by scientists studying the star S2**

Flares have been spotted coming from Sagittarius A*, the massive radio source at the centre of our Galaxy, it was recently announced. This is further evidence that Sag A* is a supermassive black hole, as has long been assumed.

The flares originate in the closest stable orbit to the Sag A*'s event horizon – the point where matter is irresistibly drawn into the black hole – where gas can reach speeds of up to 30 per cent the speed of light. The observations of the flares, taken by the Very Large Telescope (VLT), are the most detailed ever taken of material this close to a black hole.

The flares were seen in May 2018, when a team of astronomers were watching star S2 making a close pass of Sag A*. "We were lucky enough to notice three bright flares from around the black hole," says Oliver Pfuhl, from the Max Plank Institute.

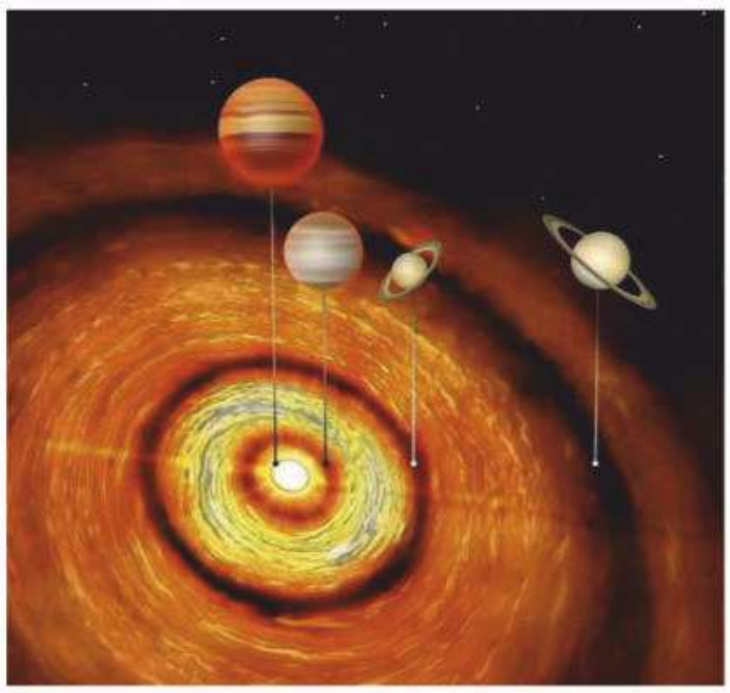
www.eso.org

Giant planet quartet

Four gas giants were recently spotted around a star, CI Tau, that is only two million years old. This is the first time so many planets have been found around such a young star and astronomers are struggling to explain how they could have formed this quickly.

Observations with the Atacama Large Millimetre/submillimetre Array revealed that the innermost planet is an example of a hot Jupiter, orbiting 1,000 times closer to the star than the outermost one. It's thought hot Jupiters are forced into their tight orbits via gravitational interactions with other worlds in their systems, and so researchers will continue studying CI Tau to gain clues about how extreme planet systems form.

www.almaobservatory.org



▲ **CI Tau's two outer planets are about the mass of Saturn; its inner ones are one and 10 times the mass of Jupiter**

ESO GRAVITY CONSORTIUM L CALCADA, NASA/KEN HODGES, MIGUEL ZUMALACÁRREGUI, ESA

LOOKING BACK THE SKY AT NIGHT
10 December 1995

On 10 December 1995 *The Sky at Night* discussed the Galileo probe, which had just arrived at Jupiter and was due to send an update.

The spacecraft began its six-year journey to the gas giant with a launch on 18 October 1989. Galileo approached Jupiter on 7 December 1995, ready to spend the next eight years surveying both the planet and its moons.

One aspect of Galileo's mission, though, was completed on its first day at the planet when an atmospheric probe descended through Jupiter's upper layers. It hit the atmosphere at 46km/s, but used a parachute to slow its plunge to 0.12km/s in just four minutes.

The probe discovered that Jupiter's atmosphere was much hotter and denser than expected though there was less water and lightning. The probe survived for 78 minutes before temperatures over 150°C caused the electronics to fail.

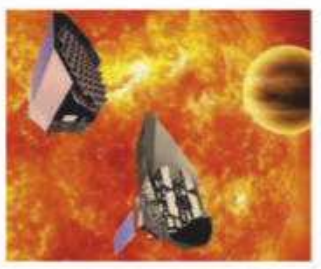
This archived episode is available on BBC iPlayer.

▲ **An artist's impression of Galileo's atmospheric probe in Jupiter's skies**

NEWS IN BRIEF

DARK MATTER NOT BLACK

Astronomers hunting for hidden black holes found they cannot be the Universe's missing mass, dark matter. A recent study looked for signs of undiscovered black holes along the line of sight to 740 supernovas, but found none. It concluded this meant black holes can only account for 40 per cent of dark matter. "We're back to the standard discussions. What is dark matter? We are running out of good options," says Uroš Seljak from Berkeley University who took part in the study.



PLATO STARTS CONSTRUCTION

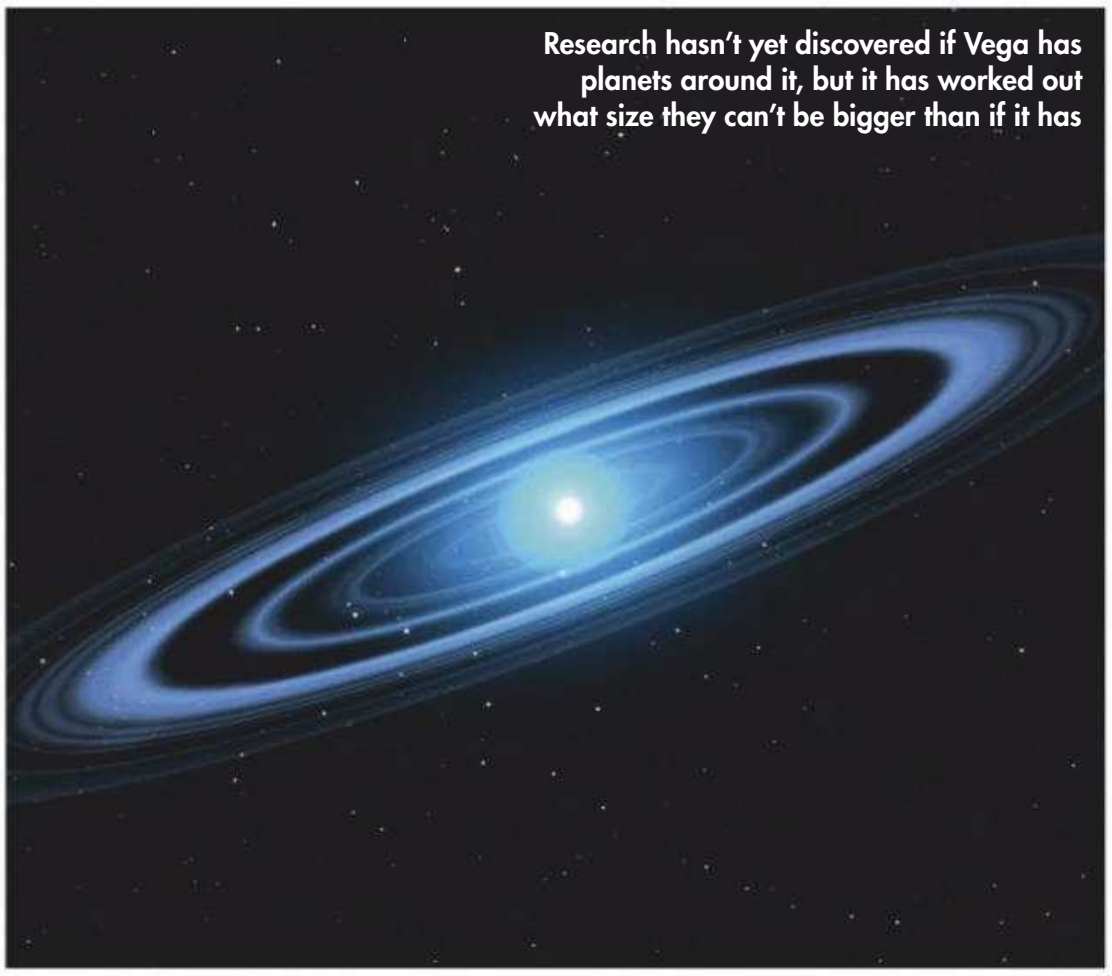
ESA began building its Planetary Transits and Oscillations of Stars (PLATO) satellite this October. The spacecraft is scheduled to launch in 2026 and will study extrasolar planet systems, particularly those with rocky worlds around Sun-like stars. Plato will not only seek to find new planets, but also determine their mass, size and age with unprecedented accuracy to help scientists build a picture of what planetary systems look like throughout the Galaxy.

CUTTING EDGE

Our experts examine the hottest new research

Planet hunting at Vega

There are signs of exoplanets around one of the sky's most famous stars, but they remain elusive



Research hasn't yet discovered if Vega has planets around it, but it has worked out what size they can't be bigger than if it has

CHRIS BUTLER/SCIENCE PHOTO LIBRARY

Vega is the second brightest star in the northern hemisphere, and was well known to ancient Babylonian, Assyrian and Chinese stargazers. It was the northern pole star when the last Ice Age was thawing 14,000 years ago, before precession of Earth's axis rolled round to align with Polaris instead. Vega was also the first star ever to be photographed – by astronomer William Cranch Bond and photography pioneer John Adams Whipple using Harvard College Observatory's 15-inch Great Refractor – in July 1850, as well as one of the first to have its distance estimated by parallax. So for many reasons, Vega is considered to be one of the most important stars in the history of astronomy. It was also significant in Carl Sagan's novel *Contact*; being the star from which humanity received an unambiguously artificial radio transmission. But does Vega actually possess any planets?

What we do know is that Vega is pretty young – about 450 million years old – and is still surrounded by a swirling disc of dust; we can see an 'infrared excess' from Vega emitted by these warm grains. This is the raw material from which new planets form around a young star. Vega's dusty disc just so happens to be orientated almost perfectly face-on to us, and astronomers have detected an inner, warmer ring of dust at around 14 AU and an outer, cooler ring between about 50 and 140 AU. Crucially, there is a large gap between these dust rings which strongly hints at the existence of several newly-formed planets that have swept clear this orbital space.

Frustratingly, though, because the Vega system is face-on to us, the most successful methods for exoplanet detection – radial velocity or transit – won't work. So instead, Tiffany Meshkat at the California Institute of Technology, Pasadena, and her colleagues have tried to directly image any large planets orbiting this bright, young star. They used an instrument installed at the Palomar Observatory to observe Vega's dusty disc whilst blocking the central brilliance of the star itself with a coronagraph.

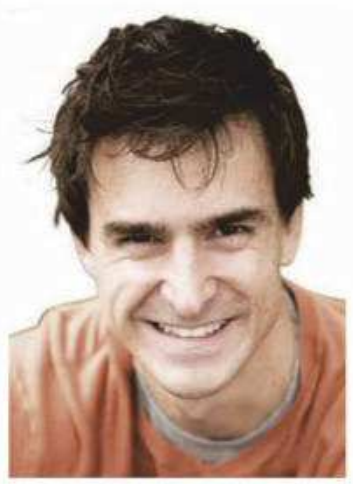
> "A key principle in science is that often not finding something can be almost as informative as actually discovering it"

And what did they find..?

Absolutely nothing. Zip all.

But this certainly isn't an anti-climax. And I think this study very neatly demonstrates a key principle in science: often, not finding something can be almost as informative as actually discovering it. The fact of the non-detection, coupled with your understanding of the sensitivity of your equipment, allows you to place tighter and tighter constraints on what could be present but yet remain undetected. In this case, that turns out to be the maximum size of any planets orbiting Vega: if they were orbiting within the warm dust belt and were any larger than 20 times the mass of Jupiter, Meshkat and her team would have spotted them.

Something is clearly sculpting the debris disc in the Vega system, and we now know a lot more about how big these planets could be, even without actually having discovered them. With the launch of the James Webb Space Telescope in 2021, and its much greater sensitivity, we will be able to spot any planets in the Vega system right down to the mass of Saturn (which is about a third the mass of Jupiter). Vega is unusually bright and nearby, and so this would offer us a spectacular opportunity to study a whole new solar system still in the making.



LEWIS DARTNELL is an astrobiology researcher at the University of Westminster and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

LEWIS DARTNELL was reading… *A deep search for planets in the inner 15 AU around Vega* by Tiffany Meshkat. **Read it online at arxiv.org/abs/1809.06941**

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NGC7635 image by Gordon Haynes www.imagingtheheavens.co.uk

The Widescreen Centre

Autumn & Winter 2018

The winter skies are returning. Time to plan ahead for the winter's observing and astrophotography! With the end of summertime, and sunset and the Pleiades rising around 4.30pm at the beginning of the month, there;s lots to see. Orion clears the horizon around 10pm. The Widescreen Centre is a real showroom you can visit and see the latest priduwhich cts and get expert advice before you buy.
Your hobby is important. You want to be sure you're getting the best. Check in with us for events around the country or here at our dark-sky site in Cambridgeshire
www.widescreen-centre.co.uk

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*Occasionally we will be closed on Saturdays for major events such as Astrofest, Practical Astronomy Show orStar Parties

Image courtesy of Joe Canzoneri

Perfect for the entry- level astronomer, the Atik Infinity is the first Atik CCD camera dedicated to video astronomy. It is supplied with our new, intuitive, in-house software dedicated to video astronomy, and is well suited to a broad range of telescopes, bringing the wonders of deep-sky imaging to your screen in just seconds.

Atik Infinity
Entry level

CCD TECHNOLOGY
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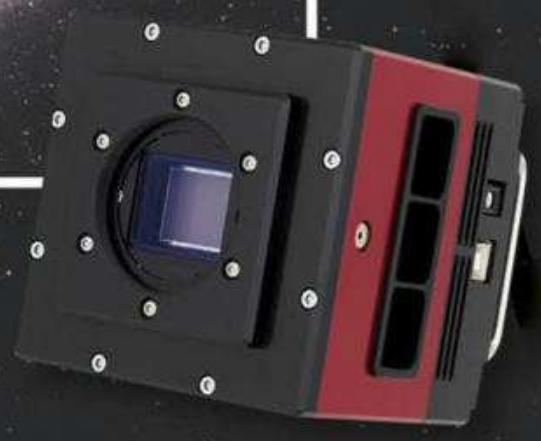
Atik 460EX
Mid range

Image courtesy of George Chatzifrantzis

The Atik 460EX is renowned for its perfect balance of sensitivity and resolution. It utilises a Sony ICX694, which is the sensor of choice for astronomers looking for the highest-quality data. Its efficiency and generous sky coverage make the 460EX one of the most versatile astrophotography cameras around, ideal for a large range of telescopes.

Atik 16200
Large Format

Image courtesy of
MASIL Imaging Team



The Atik 16200 boasts a sensor specifically designed for astronomy and having a generous 35mm diagonal. The 16million, 6µm pixel sensor can be freely binned so offers a huge amount of flexibility for both wide field and long focal length imaging. Argon purging, deep cooling and a mechanical shutter make this a camera for professionals and amateurs alike. The Atik 16200 is the camera capable of taking your imaging to the next level.

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What's on

Our pick of the best events from around the UK

▲ Herstmonceux will be celebrating the 50th anniversary of Apollo 8's Christmas voyage

Christmas Round the Moon

Observatory Science Centre, Herstmonceux, East Sussex, 8 December, 6.30pm

December marks the 50th anniversary of Apollo 8, when on Christmas Eve NASA astronauts Frank Borman, James Lovell and Bill Anders became the first humans to circumnavigate the Moon. This special open evening at the famous Observatory Science Centre will begin with a presentation on Apollo 8 by Robin Mobbs, a lead educator at the UK's National Space Academy. After that, visitors will be invited to take part in a spot of stargazing.

Interesting targets to see on the night include Uranus and Neptune along with deep-sky objects like the Andromeda Galaxy, while the constellation of Orion will be high in the sky, offering the chance to view the Orion Nebula. The open evening also coincides with the beginning of the Geminid meteor shower, one of the more regularly prodigious of the annual meteor showers.

Join the team at Herstmonceux and view some of these targets through the Observatory's telescopes. Observing is weather-dependent, so contact Herstmonceux on the day to make sure the observing is still going ahead.

Admission is £8.25 for adults, £6.25 for those under 16 and there are also group discounts for families available. For more information and ticket prices, visit the observatory website.

www.the-observatory.org/open-evenings

OBSERVATORY SCIENCE CENTRE X 4, CMRP, JODY KINGZETT/SCIENCE MUSEUM, NASA PHOTO/JIM ROSS

BEHIND THE SCENES

THE SKY AT NIGHT IN DECEMBER

BBC Four, **9 December,** 10pm (first repeat BBC Four, **13 December,** 7.30pm)*

One of SOFIA's primary goals is to study the formation of stars and stellar objects

TELESCOPE ON A PLANE!

The team look at SOFIA, a 17-tonne NASA telescope housed on a Boeing 747SP. SOFIA observes our Galaxy from about 12km high and can peer through cosmic dust into the heart of the Milky Way to see how stars form. It may even be able to answer one of the most puzzling questions: why aren't more stars being created?

Check www.bbc.co.uk/skyatnight for subsequent repeat times

Forgotten Astronomical Events and Astronomers of WWI

Room 411, Babbage Building, University of Plymouth, 14 December, 7.30pm

During the First World War, women like English astronomers Fiammetta Wilson (pictured) and Grace Cook ensured that scientific work was carried out on thousands of meteor observations while their male colleagues were off fighting. In this talk for Plymouth Astronomical Society, Sheila Evans discusses the astronomical events of those four years and the astronomers who studied them. This talk is free for members and £2 for non-members, followed by a Christmas quiz. Visit the society website for more info.

www.plymouthastro.btck.co.uk

Winter stargazing

Castle Semple Centre, Clyde Muirshiel Regional Park, Lochwinnock, 17 December, 7pm

Join local astronomer John Pressly for a guided tour of the night sky in Scotland's largest regional park, with an opportunity to view deep-sky objects through a telescope. Should clouds spoil the fun there will be an indoor astronomy-related presentation. The evening includes a Q&A session with John, making this a great event for beginners. Tickets are £5 for adults, £2.50 for children. Book at the park's website.

www.clydemuirshiel.co.uk/events

See Tim Peake's Soyuz capsule

National Museum Cardiff, all month

Get up close to the charred Soyuz capsule that brought Tim Peake back to Earth from the International Space Station. It will be on display, along with Peake's spacesuits, as part of an interactive exhibition on until February 2019. The exhibition includes a virtual reality 'journey' from the ISS back to Earth, narrated by Peake himself. The exhibition is free, but the VR experience is £6 per person and restricted to those aged 13 and over.

www.museum.wales/cardiff/whatson

MORE LISTINGS ONLINE

Visit our website at **www.skyatnightmagazine.com/whats-on** for the full list of this month's events from around the country.

To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the web page.

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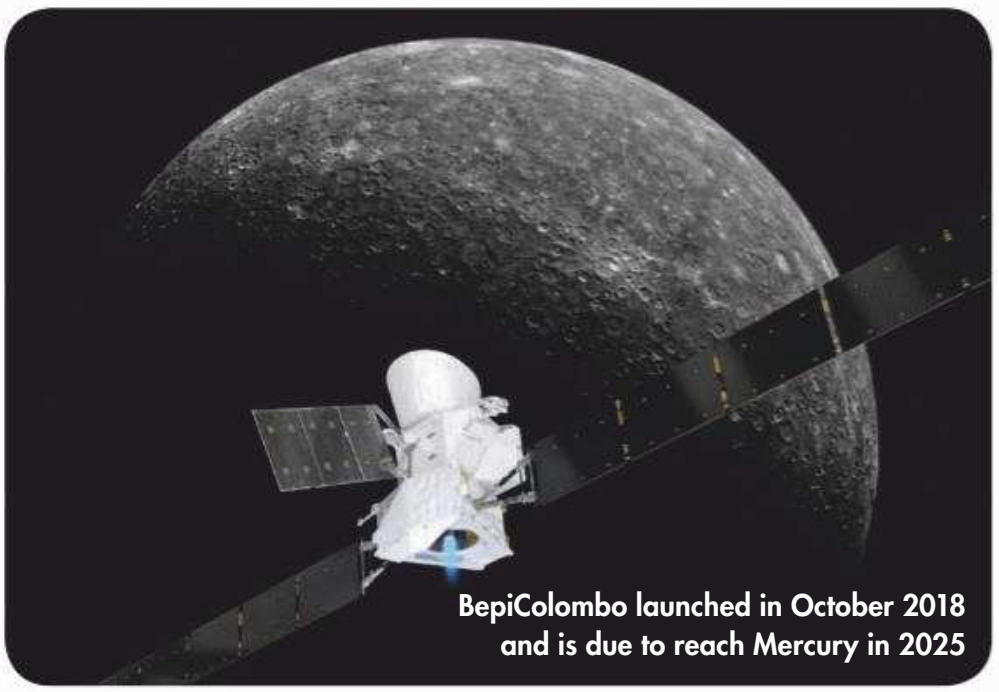
A PASSION FOR SPACE

with **Associate Professor Suzie Imber**

BepiColombo's mission to the first rock from the Sun could solve many of Mercury's intriguing mysteries

For many years our attention has been grabbed by the rings of Saturn, the ice caps of Mars or Jupiter's Great Red Spot. Missions to these planets have provided a wealth of information about our Solar System. However, there is an anomalous planet that continues to perplex scientists, so much so that we have just launched our second dedicated mission there this century: Mercury.



BepiColombo launched in October 2018 and is due to reach Mercury in 2025

Understanding the formation and evolution of Mercury may provide the key to unlocking some of the outstanding mysteries of our Solar System. It's so close to the Sun in the sky that the majority of our current knowledge has come from in situ spacecraft observations. Even getting a satellite to Mercury presents a huge challenge, requiring a seven-year journey incorporating several flybys of Earth, Venus and Mercury to slow it down enough to be captured by Mercury's weak gravitational field. And that's just the first step; the environment around Mercury presents huge engineering and operational challenges. Chief among these is the heat: orbiting spacecraft must endure temperature swings from +450°C to –180°C in periods as short as 30 minutes, while most of the instruments on board are designed to operate at room temperature.

Mercury is the densest planet in the Solar System (accounting for gravitational compression), as its metal-rich core takes up a far greater fractional volume of the planet than any other. This could be the result of a huge collision that removed the outer layers of rock, but Mercury's surface appears to be rich in the volatile elements that would be the first to disappear as a result of such a collision. How then – and where – did Mercury form?

Enduring a solar assault

Over the four years it orbited Mercury from 2011-2015, NASA's MESSENGER spacecraft made the remarkable discovery that Mercury's magnetic field is offset to the north of the planet. It also revealed tantalising hints that Mercury's space weather may be fundamentally different to Earth's, because Mercury's giant iron core is fending off the powerful solar wind in the inner heliosphere. Can the solar wind from the Sun ever scour the surface of the planet, and what impact would this have on the planetary atmosphere? Are the mysterious X-ray emissions on the night side of the planet similar to Earth's aurora, and if so, what can these features tell us about Mercury's space weather? Also, what exactly is the dark material that MESSENGER discovered on Mercury's surface, and does it play a role in the formation of mysterious holes – known as 'hollows' – on the planetary surface?

On 20 October this year I witnessed the launch of the joint European-Japanese BepiColombo mission, carrying a suite of instruments (including one built at Leicester) to Mercury. It's a pioneering mission composed of two spacecraft that will travel together until they arrive at Mercury in December 2025, then split apart and orbit the planet separately.

This configuration will enable some ground-breaking studies of the surface and environment, seeking to explain Mercury's formation, evolution and dynamics, with implications for our Solar System and beyond. It's a long journey, but I can't wait to see what discoveries our new mission will bring to light!

ASSOCIATE PROFESSOR SUZIE IMBER is a space physicist at the University of Leicester researching Mercury's magnetosphere via BepiColombo

SPACECRAFT: ESA/ATG MEDIALAB; MERCURY: NASA/JPL

FIELD OF VIEW THE AMATEUR ASTRONOMER'S FORUM

Drawn to the Universe

Educator **Deirdre Kelleghan** on why art is the perfect medium to excite children about astronomy

ANDRÉS LOZANO/FOLIO ART

A lifelong interest in astronomy, space and drawing has led me to developing workshops for children. These workshops always have an element of art or creativity involved, as drawing can cut across every perceived issue in a child's capacity to learn. No matter their ability, a child's attempt to draw a planet offers learning in the simple act of putting pencil to paper.

There are many branches of astronomy, but choosing topics for the workshops is easier than you might expect. I've found that dealing with current, tangible events has the most impact on learning, so I teach about current missions or upcoming astronomical events. Since these also have a high chance of being covered in the media, this has the bonus of bringing the subject directly into the child's home life, extending their learning experience.

It's always better to do an activity that's fun as well as educational, and something that involves a whole group working together is a big hitter in that respect. Years ago I made a model of our Moon from a huge polystyrene ball. The plan was to take a group to a field and teach them about Moon phases using a powerful torch, with the children drawing each phase as we created it. The kids were so excited: equipped with pencils and clip boards, they sketched lovely Moon phase drawings and were on their way to understanding the Moon's movements. Everything went smoothly until the end, when the kids decided they would help carry the Moon model to my car. And with little hands up in the air trying to hold the Moon – oops – it went falling to the ground, rolling down a hill with the kids running after it. Everyone was laughing!

One workshop, the Action Comet, proves time and time again that you should never underestimate what kids can draw. It's based on ESA's Rosetta Mission to comet 67P/Churyumov-Gerasimenko. Hundreds of children have drawn the comet, which is a very complex shape indeed. We also made comets from polystyrene balls with paper attached to mimic the gas and dust tails, sometimes flying our little space rocks in Earth's wind just for fun.

A big stand-out moment for me took place in Java, Indonesia, where I'd been invited to give a workshop on the Sun as part of the opening of a UNESCO-led education event. The local army donated a 3x3m tarpaulin and everyone at the event, from professors to local orphans, took part in creating an enormous Sun on it. Using data from the Solar Dynamics Observatory every sunspot, prominence and filament was made from paper with joy. The creation went on display on the floor of Bosscha Observatory under a 12-tonne telescope.

Thousands of drawings have been produced in my workshops over the past 15 years. Showing children the latest images from space, or what the Sun actually looks like, is real, sustainable education: drawing on a page is a simple pathway to enhancing their understanding. And I love every second of it! Sharing drawing techniques gives me endless pleasure, as does extending the learning by encouraging venues to hold exhibitions of the children's drawings.

DEIRDRE KELLEGHAN is an amateur astronomer, artist and educator based in Wicklow, Ireland

Interactive

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Email us at **inbox@skyatnightmagazine.com**

This month's top prize: four Philip's books

PHILIP'S

The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2019 Stargazing*.

Winner's details will be passed on to Octopus Publishing to fulfil the prize

Tales from THE EYEPIECE

Stories and strange tales from the world of amateur astronomy by Jonathan Powell

Back in the early 1980s, telescopes could be readily purchased from high street electrical shops and even the odd chemist, placed next to the tinsel in the shop windows in the festive period. My first telescope, a 60mm refractor I'd asked Santa for, duly came down the chimney one year. Trying the beastie out, I focused on a signpost a quarter of a mile away, only to be disappointed at not being seeing a fly waving back at me. In truth, my telescope was better to look at than look through. However, the failing was not with the telescope, but my expectations of its capabilities, which I only understood as I gained experience. My first scope still holds fond memories for me, as it gave me many hours of happy observing in the years that followed.

Email your own tales to Jon at TalesfromtheEyepiece@themoon.co.uk

Jonathan Powell is the astronomy correspondent for the *South Wales Argus*

Free (uni)verse

MESSAGE OF THE MONTH

When my daughter was almost seven she asked Santa for a telescope, a metal detector and a microscope. Obviously Santa brought them, but Rhianna only ever actually used the telescope. She is now almost 11 and for her last birthday her Grandpa upgraded her to the Celestron NexStar 6SE. She loves all things astronomy thanks to the patience of the guys at Sunderland Astronomical Society, who are always there to support and guide us. Rhianna's other passion is writing, and I had the opportunity see some of her work at a parents' evening recently. I thought this poem she wrote about the chosen theme – space– was brilliant, moving and thought provoking!

Sarah Ball, via email

What an evocative piece of writing by Rhianna! It touches on why many are drawn to observing the night sky. ***– Ed***

LOOK UP

Look up
What do you see?
The stars of your future
The stars of my past
The cycle of night
On its spinning wheel
Oh Sister Sky
Oh Father Space
Oh brother Unknown
Why must it be Mother Earth who watches over us?

Deep in space
A battle of ages
Balls of fire clash with warrior of the night
Galaxies of anger collide
Stars go supernova
Adding to nebulas of blood

As black holes eat the sky
Will this war ever end?
Or is it the battle of eternity?

This battle overhead
Proves our insignificance
In the movements of the Universe
I long to escape the limits that bind us
Don't you?
Don't you wish to be free?
Don't you wish to unlock the secrets of the night?
But space will always have its mysteries of darkness

Rhianna Ball
(10½ years old)

The Highlands life

Chocolate cake abounded at the September meeting of Highlands Astronomical Society with club members and visitors celebrating 10 years since the opening of our Jim Savage-Lowden Observatory. The observatory, which houses the largest public telescope in the Scottish Highlands and provides stunning views of the night sky for anyone with an interest in astronomy, is located next to Culloden Battlefield.

More chocolate cake was consumed when the public were able to meet our members and see the 14-inch Schmidt-Cassegrain catadioptric telescope in its 3m rotating dome along with our club's other observatory telescopes and examples of our activities at a Highland Council-supported Doors Open Day event. Families were entertained with astronomy-related games and learned of our Youngstars group for children aged 8-14 years.

Highlands Astronomical Society is a very active club with public observing

Tweets

Jo McLaren Dunn
@jemdunn • Oct 8
Star! It had to be #sirpatrickmoore #patrickmoore #skyatnight #inktober #Inktober2018 @skyatnightmag in acrylic inks. He always fascinated me when I used to sneak down the stairs when I was little and see him on TV.

sessions scheduled throughout the long, dark, clear nights of winter, substituted by solar observing in the summer. We're always keen to welcome new members, so if you want to attend one of our public observing sessions or our monthly meetings, please do.
Eric Walker, via email

iPad-captured Moon

I am new to astrophotography and have endured many cold nights trying to capture a photograph of the Moon I can be proud of. This afocal image was taken with my iPad mini, up to the eyepiece and with a steady hand. I have seen many Moon photographs showing Mare Crisium before, but I feel my time spent looking up to the heavens has finally been rewarded. The picture was taken with a Celestron AstroMaster 130EQ MD reflector, a 20mm Celestron eyepiece, a German equatorial mount and an Apple iPad Mini.
Neil Hartley, Burnley

DIY kit building

I had to cater for some friends at an eclipse party and made a pinhole projection device with a robust cardboard tube four inches in diameter and 25 inches long. A second (viewing) tube, two inches in diameter, was melded into one end at an angle and glued into place. Both ends of the main tube were covered in stiff white paper and the opposite end of the viewing tube was pierced centrally with a needle. The main tube was then rested on the viewer's shoulder with their back to the Sun, and with care (and much patience) it was possible to see the projected solar image without fear of eye damage.

A recent house move meant my main telescope – a home-built 6-inch Newtonian, including 300 hours of mirror grinding and polishing – had to be dismantled and my enthusiasm for cold nights waned. But sunspots always hold their fascination and so I cut the pinhole projector's main tube at 17 inches, glued a jam-making funnel to the non-viewing end, formed an interface tube with my bird-watching telescope using a fibreglass repair kit for strengthening a toilet roll tube, and now have a sunspot observation tool of some capability. Unfortunately, it seems I have created this device at a Maunder Minimum!
Roger Clay, Rye, East Sussex

SOCIETY in focus

Kernow Astronomers is a mid-Cornwall group of about 40 amateur astronomers with a wide range of expertise and knowledge. We meet twice a month at St Columb Major Academy, often to hear expert speakers, and at Trevarrian on the north coast for practical observing during the darker months. Through our informal and fun meetings we invite newcomers to learn about all things space.

As a club we also bring our love of astronomy to the wider public. Some of our members visit schools or other groups to give talks, and we link with the National Trust to put on free 'Sun, Stars and Planets' evenings three times a year at its dark-sky coastal site at Carnewas near Newquay. Visitors are treated to a guided tour of the Sun, planets, stars and nebulae with a range of large scopes on hand, some constructed by members.

Also, twice a year the National Trust invites us to the Tudor house and grounds at Trerice to put on a static display, demonstrations, a video show and a line-up of telescopes. On 20 October we had a crystal-clear Cornish autumn sky in which Saturn, Mars and the Moon were shining brightly. Amazingly, nearly 400 people, young and old, turned up to view these sights and they were not disappointed. It is always a thrill to get a, "Wow!" or, "Amazing!" as Saturn's rings or the mountains of the Moon are seen for the first time, and very satisfying to be asked so many searching questions about space by excited new viewers of the night sky. Long may it continue!
www.kernowastronomers.com
Glynn Bennallick, publicity officer, Kernow Astronomers

Meanwhile on FACEBOOK...

WE ASKED: What was your highlight of 2018?

Simon Whitfield
The twin Falcon Heavy boosters landing vertically side by side is an image that will stay with me for a while. Very impressive.

Vicki Pink
The launch of the Parker Solar Probe.

Aprill Harper
Assisting a total newbie, along with the Sandy Astronomical Society, to put together a scope gifted to them a while back, then showing them Mars and the ISS.

Richard Steltner
I met Britain's first astronaut, Dr Helen Sharman.

Stephen Cheatley
I saw the clearest view of the Milky Way in UK in years whilst on Anglesey. Jaw dropping.

Natalie Penwill
SpaceX leaving a Tesla in orbit. It's so unbelievable to imagine a car floating in space!

Kevin Andrew Hasson
The Andromeda Galaxy shrank! Our Milky Way expanded! The black hole at the centre of our Galaxy was joined by thousands!

Gillian Rushforth
My northern lights experience in a northern Iceland winter and the constellations were the clearest I've seen anywhere – magical.

John Maclean
Being frozen to the ice while, idiotically, lying down to look at the stars in the Antarctic. My friends had to free me with a shovel!

BBC

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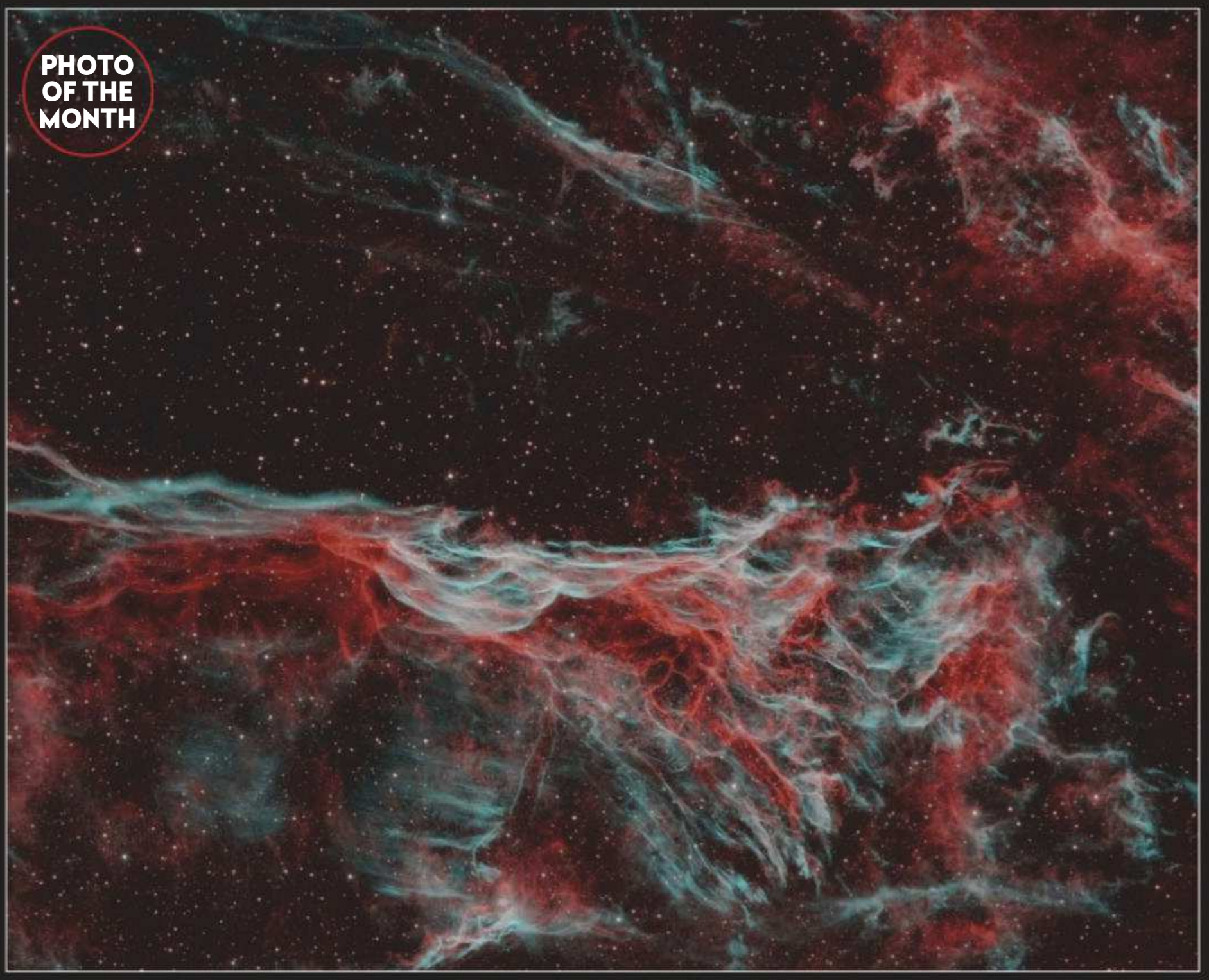
BBC Sky at Night MAGAZINE

Hotshots

This month's pick of your very best astrophotos

YOUR BONUS CONTENT

A gallery containing these and more of your stunning images



▲ Pickering's Triangle

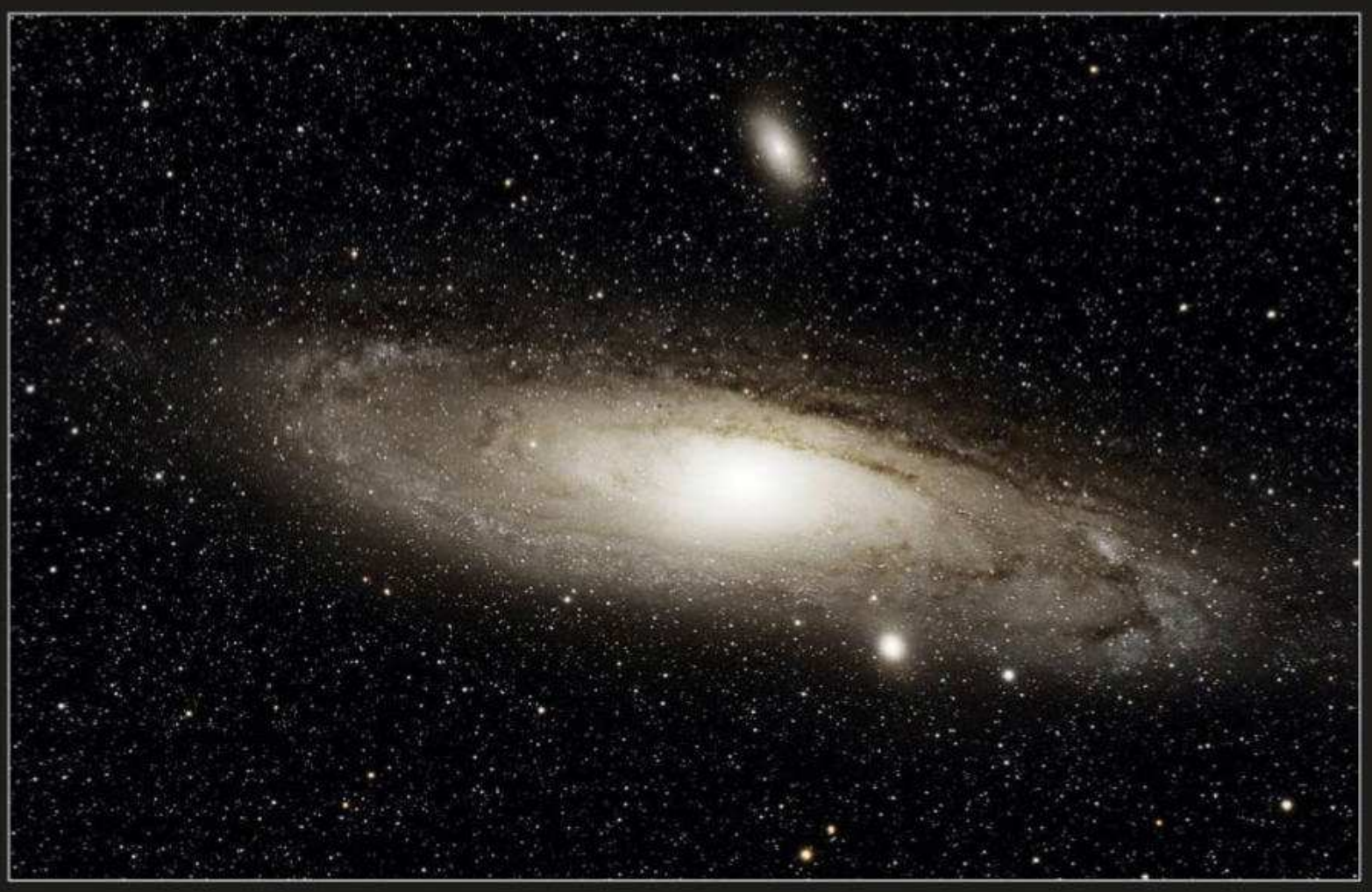
JEAN M DEAN, GUERNSEY, 23 JULY – 7 AUG 2018

Jean says: "I find the Veil Nebula fascinating; the scattered remains of the supernova have created some amazing filamentary structures that I wanted to capture. I created two synthetic RGB versions, one as normal and one without stars. I removed the stars from the individual monochrome narrowband images before combining into a starless version. Each RGB was stretched separately and then combined into a final blended version. I think this gave additional depth and detail to the image."

Equipment: Starlight Xpress Trius mono CCD camera, Takahashi FSQ-106 refractor, Sky-Watcher AZ EQ6-GT mount **Exposure:** 13x20′ each for Ha, OIII, SII **Software:** PixInsight, Photoshop

***BBC Sky at Night Magazine* says:** "Jean's image is so detailed and crisp that the features almost look 3D, as if they were protruding from the page. Other images we have seen of this object are very faint, and pale in comparison to this winning astrophoto."

About Jean: "Growing up in the Apollo era I developed a fascination for space exploration and astronomy. My passion for astrophotography has grown from that and every time a new deep-space object appears on my sensor I still get a feeling of amazement that I have just recorded a very distant moment in the history of the Universe."



◀ The Andromeda Galaxy

VITTORIO MARINONI, AOSTA VALLEY, ITALY, 8 SEPT 2018

Vittorio says: "I wanted to image some deep-sky objects but alignment problems meant I could only aim at something clearly visible."

Equipment: Canon EOS 4D DSLR, Tecnosky 90/600mm triplet refractor, Celestron AVX Go-To mount
Exposure: 25x180"
Software: PixInsight

The Milky Way ▶

THOMAS RÖELL, JOSHUA TREE NATIONAL PARK, CALIFORNIA, US, 10 SEPT 2018

Thomas says: "I'm an airline pilot, so when I had a flight to LA during new Moon, I planned a trip to Joshua Tree during my layover."

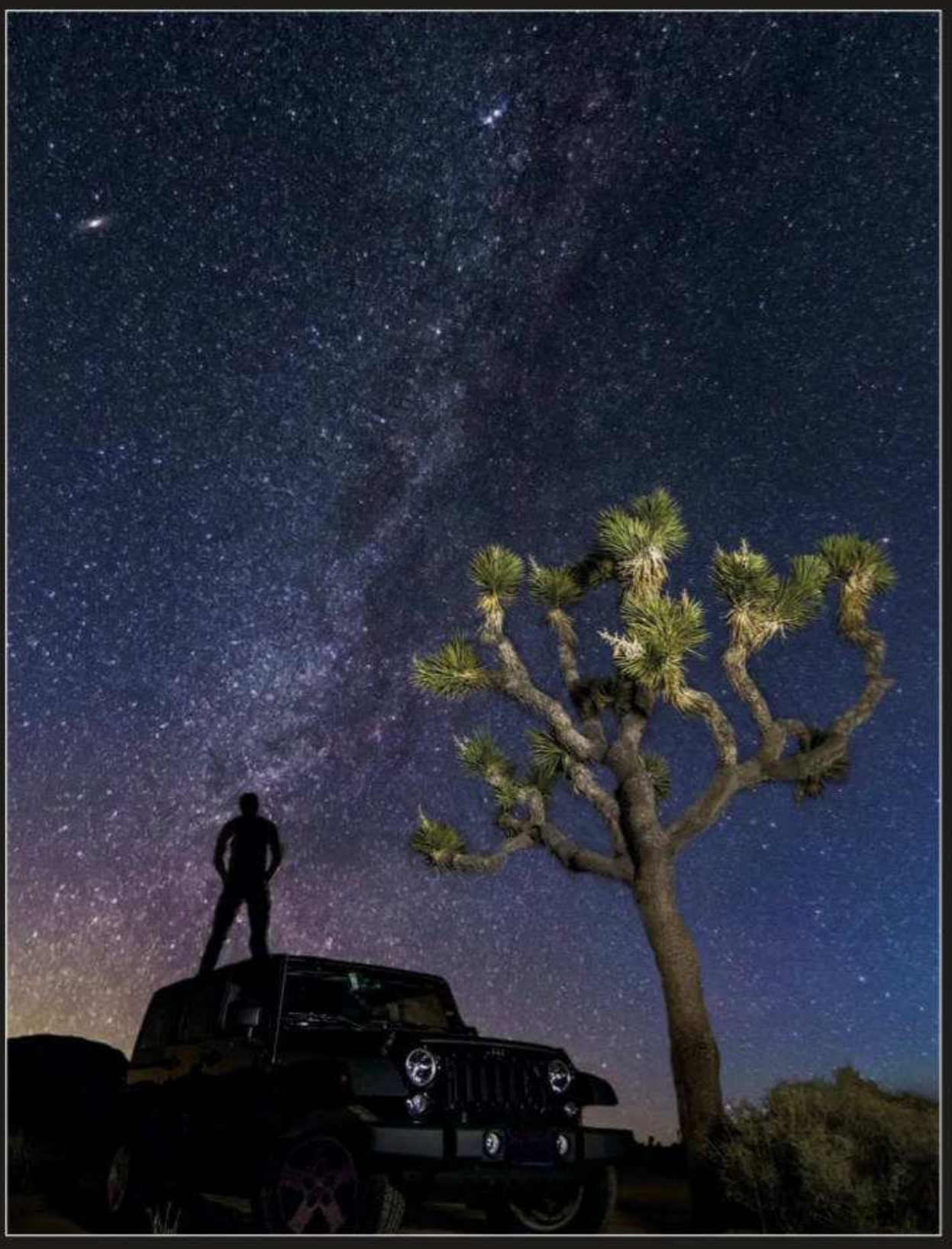
Equipment: Canon EOS 80D DSLR, Sky-Watcher Star Adventurer mount, Tokina 12-24mm lens
Exposure: ISO 1600, 7x25", 5x2-10"
Software: Lightroom, Photoshop

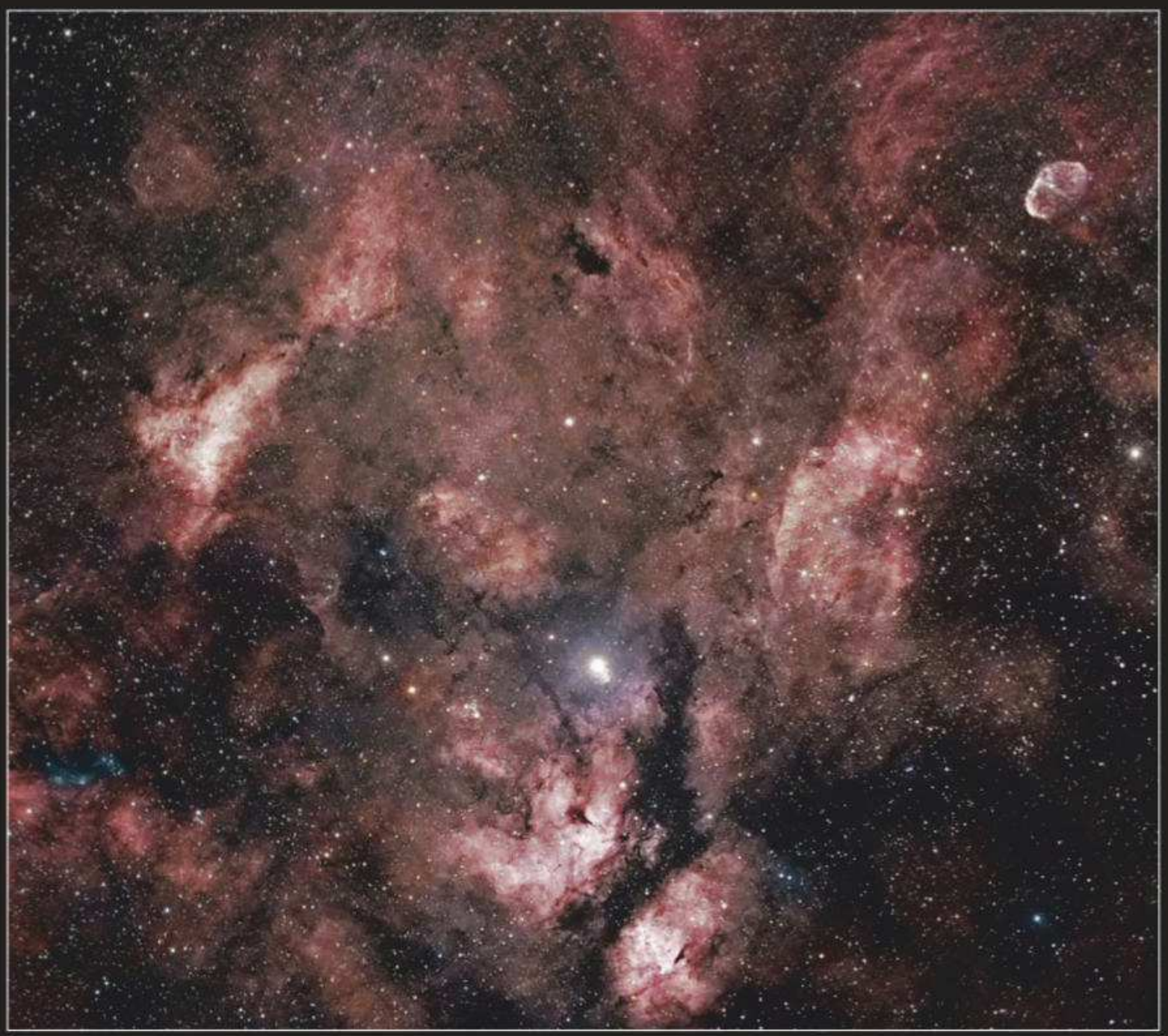
▲ The Dumbbell Nebula

GEORGES CHASSAIGNE, FREGENAL DE LA SIERRA, SPAIN, 20 JULY 2018

Georges says: "I chose this object to test my new 20-inch telescope. The focal length is 4m, which lets me capture a lot of the fine details of this planetary nebula."

Equipment: SBIG STX-16803 camera, Astrosib RC500 Ritchey-Chretien, Astrosib FM700 mount **Exposure:** 10.5h Ha, 8.5h OIII
Software: The SkyX, PixInsight





◀ Sadr region

DAVID SLACK, NORTHUMBERLAND, 10 SEPTEMBER 2018

David says: "My biggest worry was having gaps when joining the images together as I hadn't used any software to calculate the frames; I did it by eye using the preview on my laptop screen. I really enjoyed the challenge of processing it."

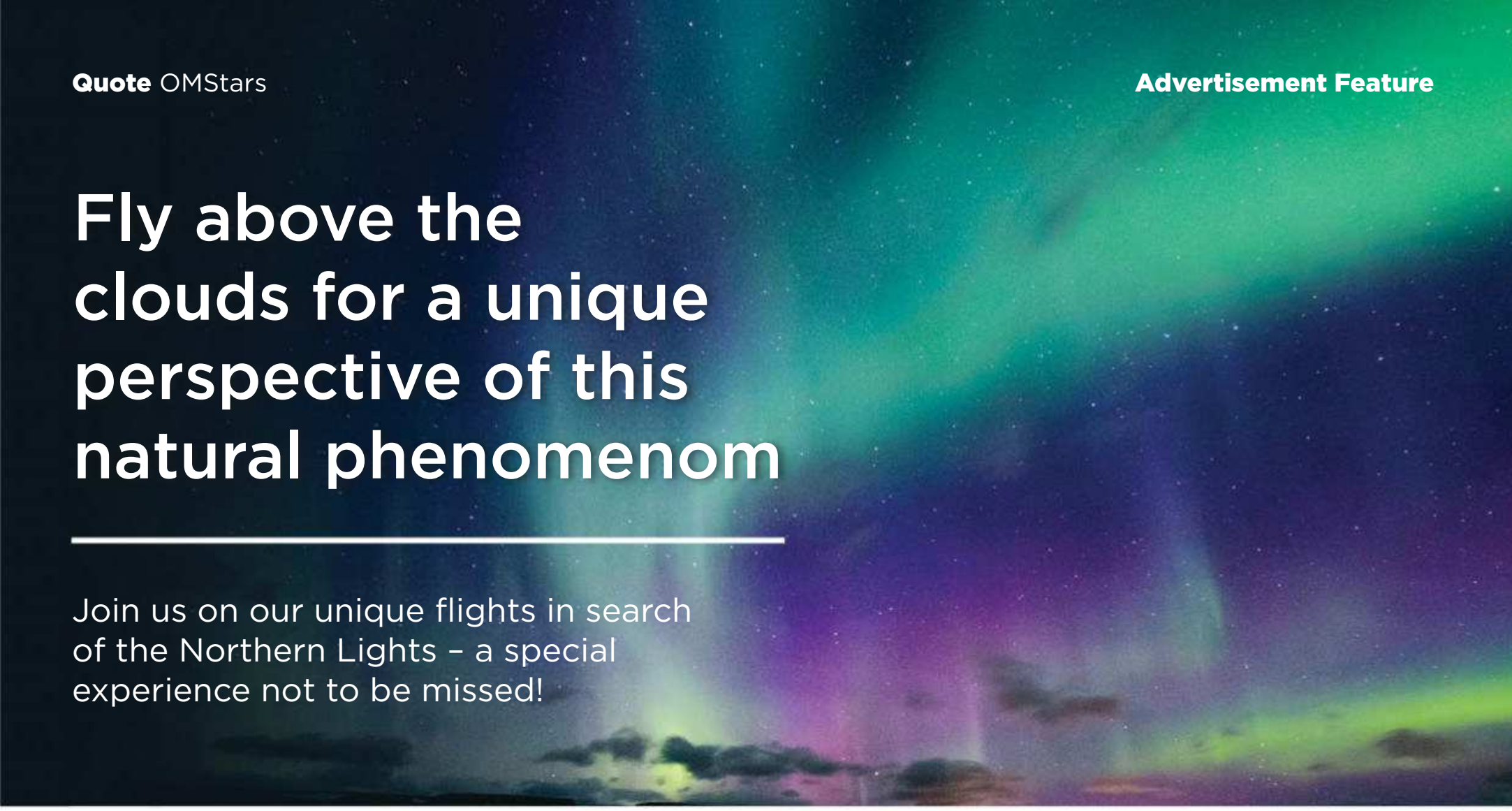
Equipment: Starlight Xpress SXV-H9 mono CCD camera, Takumar 135mm lens, Sky-Watcher HEQ5 Pro GoTo mount **Exposure:** 49x5' **Software:** DeepSkyStacker, Microsoft Image Composite Editor, Photoshop CS5

The Iris Nebula ▶

KEVIN STEWART, NORTHUMBERLAND, 7 SEPT 2018

Kevin says: "My goal was to capture the dark dust clouds, so the picture was framed to show the dark dust leading to the nebula. This was my first attempt at capturing dust clouds and I'm thrilled to say when this was processed they were viable."

Equipment: Canon EOS 1100D DSLR camera, Sky-Watcher 130PDS Newtonian, Celestron CGEM mount **Exposure:** ISO 1600, 24x300" subs **Software:** DeepSkyStacker, PixInsight, Lightroom



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2019
A year of celestial wonders

Will Gater previews the sights we have to look forward to in 2019

ABOUT THE WRITER
Will Gater is an astronomy writer and presenter. Follow him on Twitter at @willgater or visit willgater.com

WILL GATER

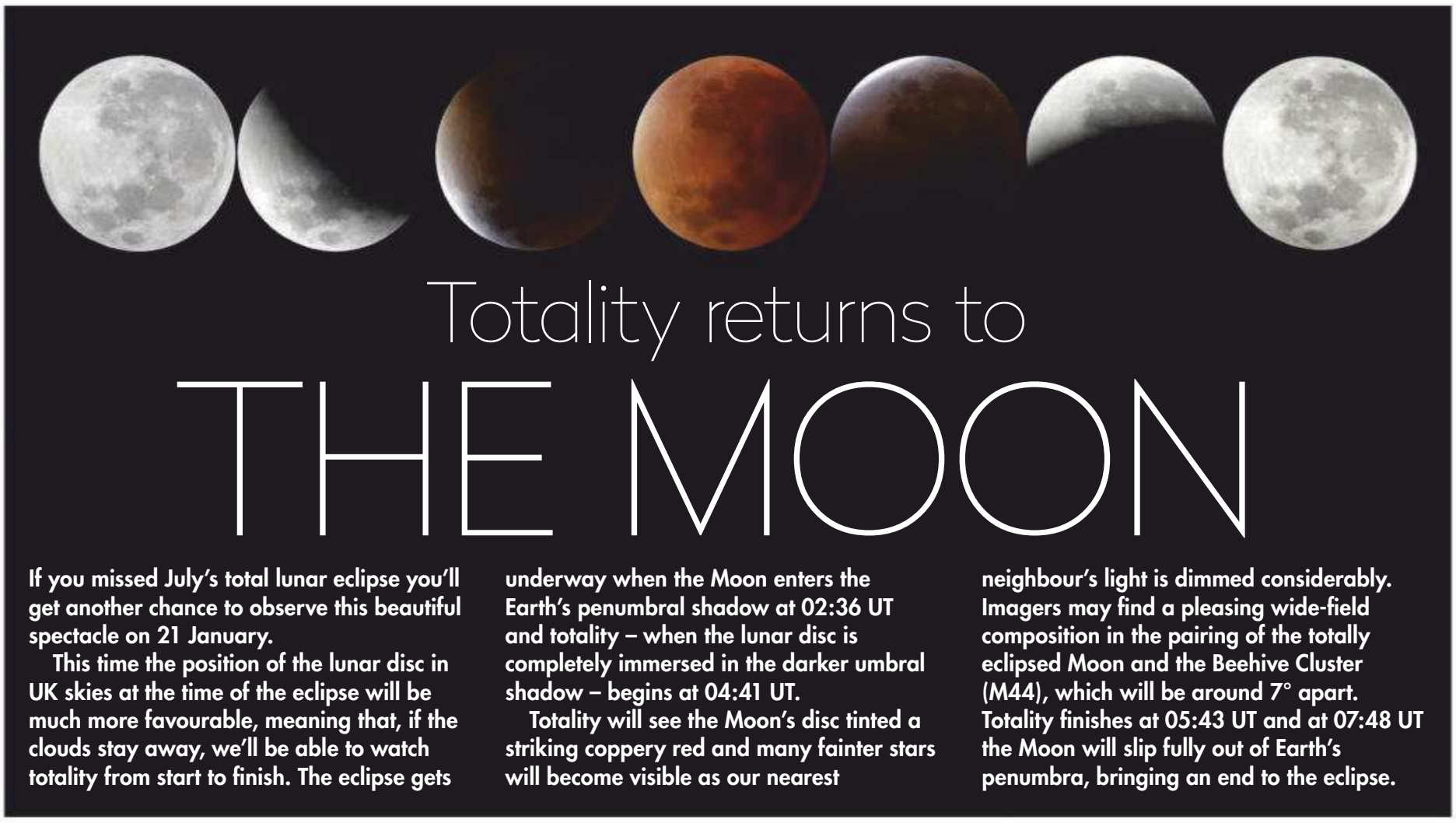
As the Sun sets on 2018, we thought we would take this opportunity to look forward to what we can expect in the night sky in 2019. Keen imagers and observers will certainly have a packed schedule right from the very get-go with Comet 46P/Wirtanen still around (hopefully), a total lunar eclipse, a meteor shower and some fine planetary gatherings all within the first few months of the year. And the rest of 2019 boasts plenty more sights too – in addition, of course, to the ever-revolving backdrop of constellations and celestial objects that come with each season.

So read on as we highlight the key dates for your diary in 2019, a veritable year of celestial wonders. ▸

If you want to capture the Summer Milky Way, you'd do best to wait until astronomical darkness returns in late July

Comet Wirtanen still on show

All being well, as this issue hits the newsstands Comet 46P/Wirtanen will be putting on a show as it climbs higher in the December skies (find out more in this month's Sky Guide on page 52). Come 2019, though, the comet will hopefully still be visible in binoculars. At the start of January it will be in the constellation of Lynx, but will move into Ursa Major on 12 January. By then it should have faded conspicuously, but since it will be high in the sky it may, nonetheless, be an interesting target for dedicated imagers and observers.



Totality returns to THE MOON

If you missed July's total lunar eclipse you'll get another chance to observe this beautiful spectacle on 21 January.

This time the position of the lunar disc in UK skies at the time of the eclipse will be much more favourable, meaning that, if the clouds stay away, we'll be able to watch totality from start to finish. The eclipse gets underway when the Moon enters the Earth's penumbral shadow at 02:36 UT and totality – when the lunar disc is completely immersed in the darker umbral shadow – begins at 04:41 UT.

Totality will see the Moon's disc tinted a striking coppery red and many fainter stars will become visible as our nearest neighbour's light is dimmed considerably. Imagers may find a pleasing wide-field composition in the pairing of the totally eclipsed Moon and the Beehive Cluster (M44), which will be around 7° apart. Totality finishes at 05:43 UT and at 07:48 UT the Moon will slip fully out of Earth's penumbra, bringing an end to the eclipse.

Venus visits the GAS GIANTS

As blazing Venus tracks across the sky at the beginning of 2019 it makes two close approaches to the planets Jupiter and Saturn. The first planetary pairing occurs on 22 January when Venus will be around 2.5° away from Jupiter in the predawn night sky. This has the potential to be a rather nice astrophotography subject – particularly over something like a glittering sea horizon – as the pair will be sitting in a brightly moonlit sky. Similarly on the 17, 18 and 19 February Venus – now much lower in the sky during the darkness preceding early morning twilight – will pass close to Saturn.

Jupiter and Venus had a close encounter in 2015 and will again next year

ISTOCK, WILL GATER X 3

Saturn and the Moon's dance in the predawn

For sites in the far southeast of the UK, Saturn will be emerging from behind the dark limb of the crescent Moon on 2 February as the latter rises in the predawn sky. It'll be a tricky observation, however, as the action will be happening when the pair is about 2-2.5° above the southeast horizon. For observers and imagers elsewhere in the UK the close pairing of the planets that morning will still provide an interesting target. Wherever in the country you view or image the event from, ensure you conclude your observations well before sunrise.

The Perseid meteor shower in 2019 will be at the mercy of a gibbous Moon

A mixed bag of meteor showers

Out of the main meteor showers that occur each year – the Quadrantids, the Perseids and the Geminids – only the Quadrantids have a favourable lunar phase on the night of their anticipated 2019 peak. The Quandrantid peak is on the evening of 3 January; the shower has a theoretical Zenithal Hourly Rate (ZHR) of 110 but the actual number of Quadrantids you can expect to see on the night of the peak will typically be lower due to light pollution, the altitude of the radiant (the point on the sky where shower meteors appear to come from), cloud cover and the fact that your eyes can't see the entire sky at any given moment. For the Perseid peak on 12/13 August, there's a gibbous Moon up most of the night and for the Geminid peak on 14 December the bright gibbous Moon is actually in Gemini – so for both showers you'll likely have to wait for the occasional bright meteor to cut through the moonlight.

What will 2019's noctilucent cloud season bring?

Noctilucent clouds (or NLCs) can appear in the summer night skies in the northern hemisphere when the layer of high atmosphere known as the mesosphere cools to a sufficient level to allow clouds of ice crystals to form there. These beautiful tendril-like, wave-shaped clouds are so high up that they are able to catch the light from the Sun below our horizon and scatter it back down to Earth where, for us looking on, it's night time. The result is a spectacular sight, typically low on the northern horizon, around 1.5-2 hours after sunset (or the same time before sunrise) with the clouds themselves taking on whitish and sometimes electric-blue colours. The NLC season usually begins around late May or early June and starts to draw to a close by August. 2018's season as seen from the UK saw a handful of extensive and bright displays on clear nights, but what will 2019's bring? Will we see the incredible sky-spanning shows like those seen widely in 2009 and 2010? As always, the fun is… we don't know! ▸

Noctilucent clouds are a beautifully eerie summertime phenomenon

Imagers should be ready for a photo op in mid-February when the Moon has an encounter with the Hyades

The Moon cosies up to some clusters

Astrophotographers will have some interesting challenges in 2019 when it comes to imaging the Moon in proximity to several star clusters. On the night of 13/14 February, for example, it'll sit within the Hyades star cluster in Taurus; under clear, transparent skies it should be possible to capture an interesting time-lapse of the bright lunar disc drifting through this collection of bright stars. On 28 July the Moon, then a crescent, will be close to Aldebaran and the Hyades as it rises just before 02:00 BST (01:00 UT). A trickier challenge occurs close to moonset on 11 May when the six-day-old Moon comes to within about 1° of the Beehive Cluster (M44); since the cluster stars are much fainter than the Moon you will almost certainly have to overexpose the lunar disc to show the two in the same shot. But with careful framing the view would definitely make a really striking composition with, say, a silhouetted horizon.

A partial lunar eclipse in July

As the full Moon rises on 16 July its bright disc will be partly immersed in the dark core of the Earth's shadow known as the umbra. This 'partial' lunar eclipse should be quite a sight under clear, transparent skies with the rising Moon appearing to have a chunk taken out of it – albeit a chunk with a rather diffuse edge that will differentiate it from the harsher edge of the terminator; it's be in a totally different orientation, too. The Moon will be showing the maximum point of this incursion (around 65 per cent) at roughly 10:30 BST (09:30 UT), when it will be about 7° above the southeast horizon from central UK. The eclipse will conclude when the lunar disc leaves Earth's penumbral shadow at 01:17 BST (00:17 UT).

WILL GATER X 2, ISTOCK, WWW.CCDGUIDE.COM X 4

A total solar eclipse over South America

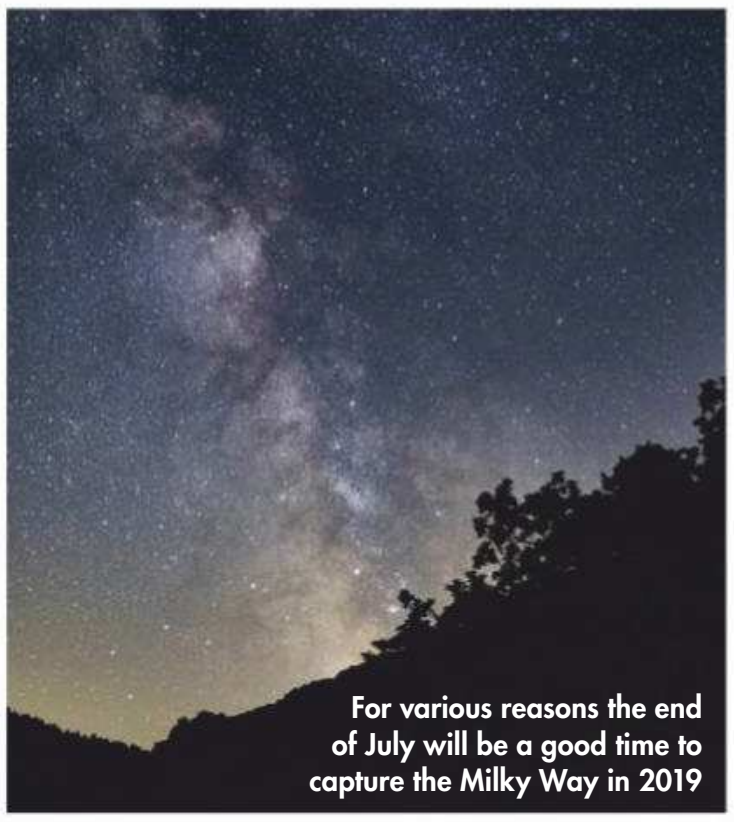
The path of July's total solar eclipse will cross Chile and Argentina

If you're thinking of booking a last-minute getaway in 2019, there'll be a total solar eclipse visible from a thin swathe across South America on 2 July next year. The Moon's umbral shadow will travel across the Pacific Ocean before making landfall in Chile near the city of La Serena. It'll then cross Chile and head into Argentina before slipping off the Earth completely. There will also be an annular solar eclipse visible from parts of Asia on 26 December. For the entirety of this December annular eclipse and the partial phases of the July total eclipse you'll need to use a specialist certified solar filter to view the unfolding spectacle.

DARK SKY DATES
for the diary

If you're a deep-sky or nightscape astrophotographer planning imaging trips next year, make sure to note the date (for your intended shooting location) when astronomical darkness ends and returns in the summer. From central UK there's no astronomical darkness from roughly mid-May to late July. The further north you go the longer this period lasts and the lighter the night-time skies will be. This shouldn't preclude all astronomical observation, though, as despite the brighter twilight skies, sites further north in the UK are prime positions from which to spot noctilucent clouds (see page 35).

The return of astronomical darkness for central and southern UK in 2019 will be a good time to photograph the bright band and rich star fields of the summer Milky Way. The central region of our Galaxy – home to the exquisitely contrasting dark dust lanes and bright regions in Sagittarius, Scutum and Ophiuchus – will be nicely positioned in the south-southwest in the last few days of July. And with the waning crescent Moon not rising until later in the night you should have ample time to photograph the Galaxy before it has sunk further toward to the southwestern horizon.



For various reasons the end of July will be a good time to capture the Milky Way in 2019

Comet 289P/Blanpain in December's skies

We started this article with a comet so it's only fitting we should end with one too. Comet 289P/Blanpain should be an interesting target for astrophotographers and keen comet observers during the latter half of November and into December. By the time the Moon has moved out of the way in mid-December it will be moving from Aquarius into neighbouring Pisces. On 13 and 14 January 2020 it'll be close to some of the star clusters in Casssiopeia providing some excellent photo ops for experienced comet imagers.

THE PLANETS IN 2019

There's still a chance to catch the planets before they sink too low to the horizon

2018 has been lacklustre year for planetary observers in the UK with Mars, Saturn and, to a lesser extent, Jupiter all sitting low in the sky where poor seeing and haze has often combined to frustrate high-resolution imaging and observation. So what does 2019 hold for those interested in our cosmic neighbours? The picture's not much better, unfortunately.

Jupiter reaches opposition on 10 June when it will be in the bright Milky Way star fields in the southern half of Ophiuchus. From the central UK, though, it will only reach an altitude of around 15° at this time.

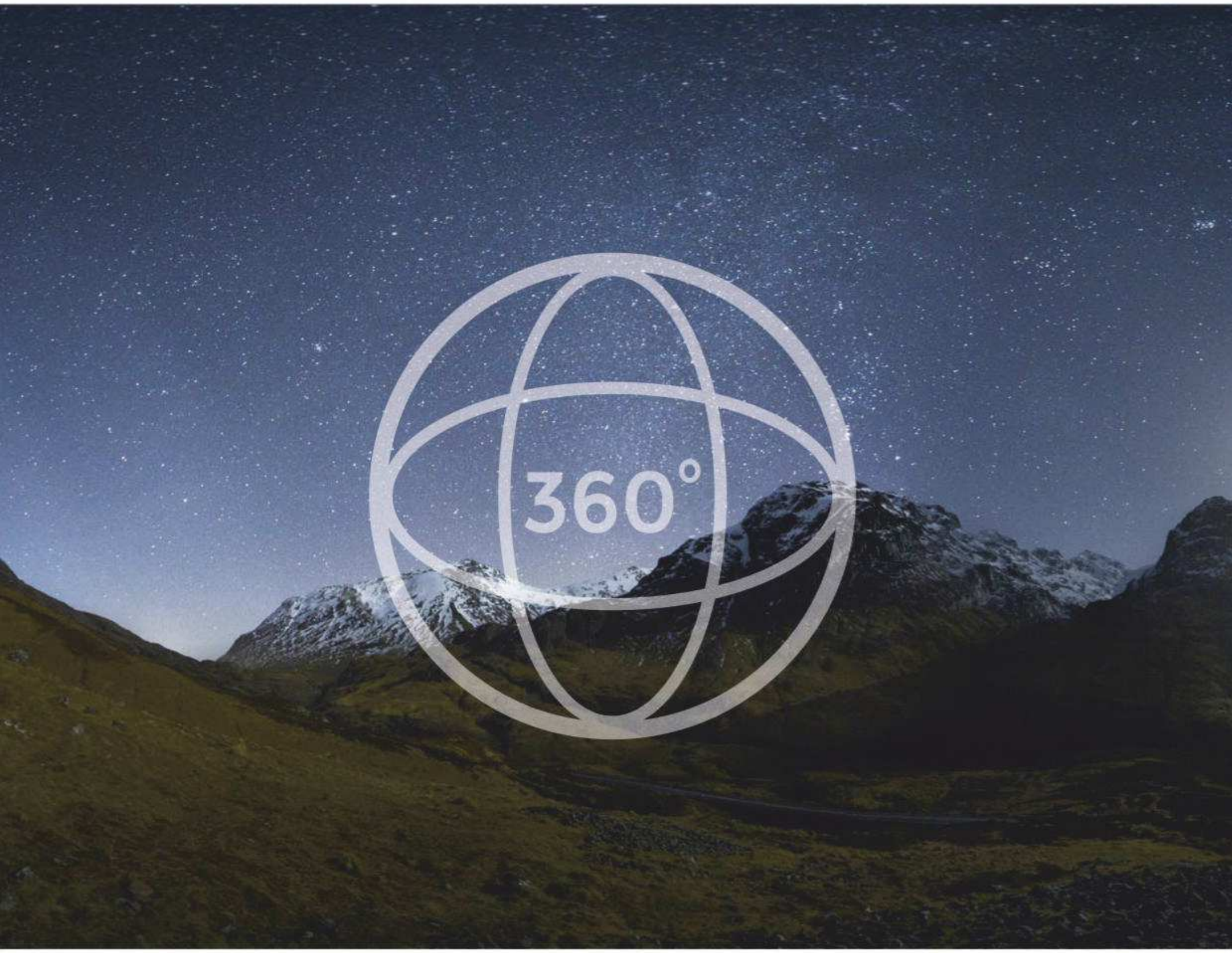
Saturn, meanwhile, reaches opposition on 9 July in the constellation of Sagittarius, but like Jupiter will only be around 15° above the horizon from the centre of the UK.

At the beginning of the year Mars is in Pisces, but its apparent diameter will have already shrunk considerably since its opposition in July of this year, and it won't be until October 2020 that it'll be at opposition once again. That being said it will have a close approach with the Pleiades in late March and early April, which should make a beautiful photo opportunity for wide-field imaging with the contrast between the Red Planet and the cluster's blueish stars.

In the inner Solar System Venus reaches greatest western elongation on 6 January and only begins to become prominent again in the evening sky – in the west – in the last few weeks of December. Good times for spotting Mercury in 2019 include after sunset on the nights of 25, 26 and 27 February and in the darkness before dawn on 27, 28 and 29 November.

In the distant reaches of our planetary neighbourhood, Uranus is at opposition in the constellation of Aries on 28 October while Neptune is at opposition in Aquarius a few weeks earlier on 10 September; as always both these worlds are tremendously rewarding to track down through a medium-to-large aperture telescope.

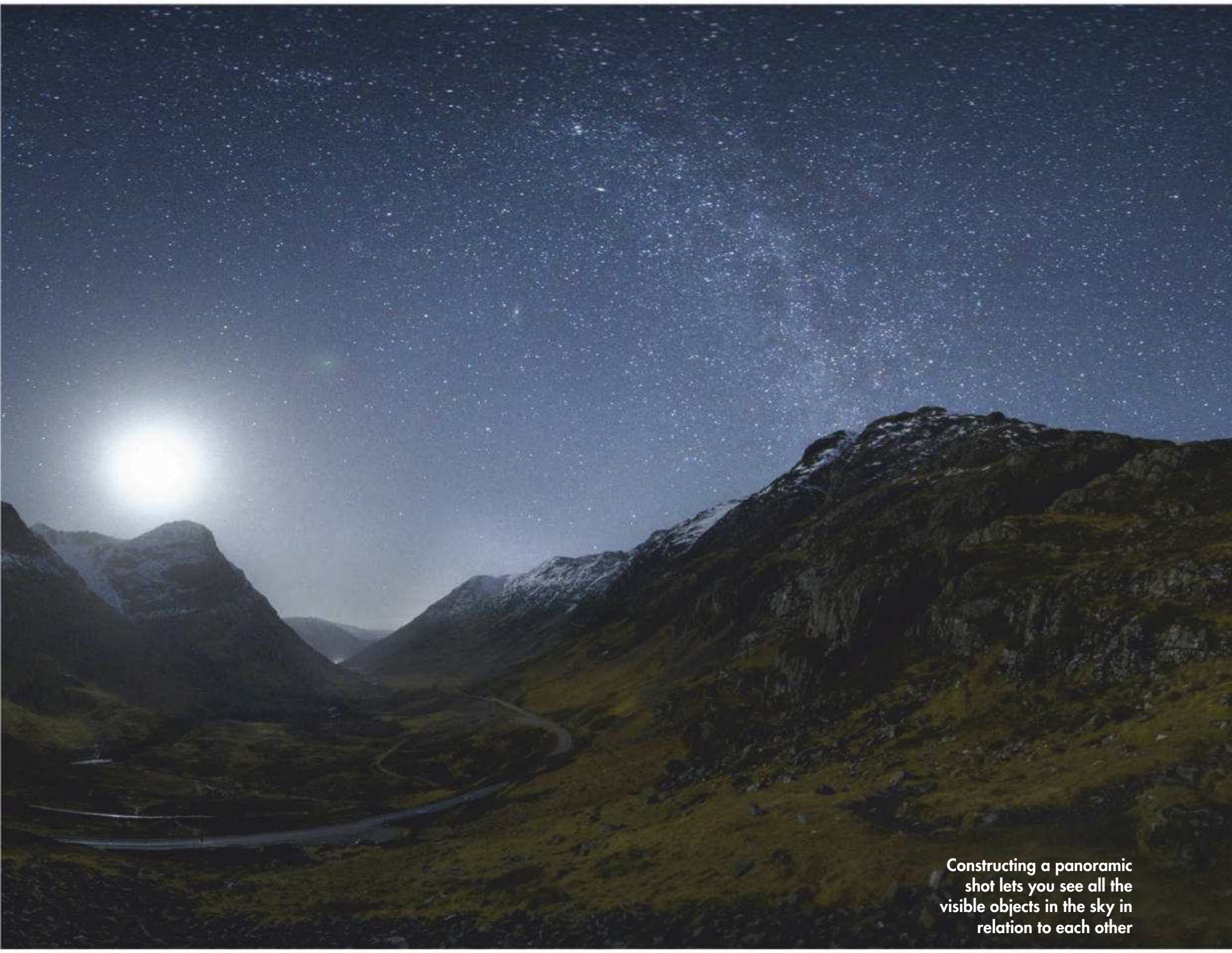
360° VISION



CREATING A NIGHT-SKY PANORAMA

ABOUT THE WRITER
Stuart McIntyre is a professional photographer with a passion for the night sky and the hills of the Scottish highlands

Professional night-sky photographer **Stuart McIntyre** reveals how you can start creating stunning, immersive views of the night sky



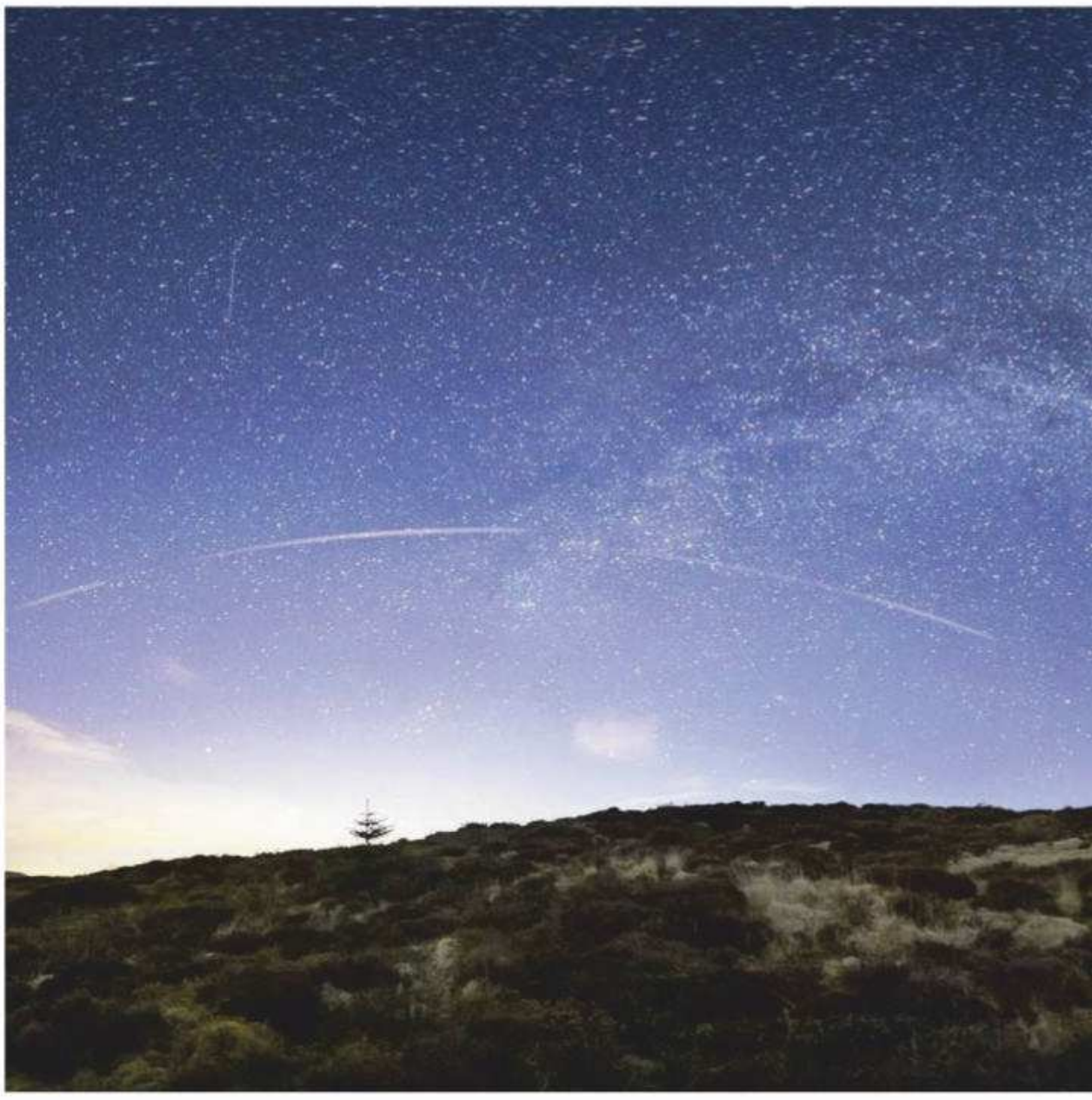
Constructing a panoramic shot lets you see all the visible objects in the sky in relation to each other

STUART MCINTYRE, ISTOCK

Creating a panorama can be a bit of an art. Many aspects need to be considered, and in this article we're going to explain how to capture the images to form a 360° picture, as well as the equipment needed to do it. You'll find it a very rewarding experience once you start to see the image come together.

So what is a panorama? Put simply, it's a 360° picture made up of multiple images taken from one location. They can't be any old images, though: to get the best results you need to take non-parallax images, where there's no perspective change as your camera is moved. It's also best not to spend more than 20 minutes taking the images that will be combined: any longer than that and the Earth's rotation will cause the stars to shift positions. To minimise this star shift, it's also better to shoot in rows first, then columns so you can photograph the sky faster. You also want the images to overlap so that they can be easily combined later.

Lens choice plays an important role in the capture technique. I typically like to work at f/2.8; it lets plenty of light into the image but also allows for a ►



▸ pleasing depth of field. The other advantage of using a wide aperture is that as the camera moves, the edge of one image can be the centre of the next. Wide apertures will generally produce more vignetting, however, and while this can be corrected after capture, there's a risk of noise entering the image and creating a 'blotchy' final picture. I've shot at f/2.0 but wouldn't recommend going wider than that, as coma (blurring) and other lens aberrations can become evident at the edges of an image.

Exposure time is crucial too and the '500 Rule' is invaluable here. According to this, you divide 500 by the camera's focal length to get the number of seconds you can expose for before star trailing becomes an issue. So with a 24mm lens, 500÷24mm = 20.8 seconds, which means the stars will start to trail with any exposures longer than that. Most cameras have a long-exposure noise-reduction option; this makes the camera take a second image immediately after the first to record the noise of the sensor. The camera will then automatically subtract this noise from the photo, effectively doubling the exposure time. If exposure time is an issue or your camera doesn't have this function, it's possible to take a single dark frame image with the lens cap on and the eyepiece covered, which can then be subtracted from the photo manually. Doing this can be very time consuming, though and in reality, it doesn't save as much time as moving the camera to the next position while the dark frame is exposing.

The theory

As previously mentioned, the images need to overlap. Generally I have a 30 per cent overlap, which makes stitching the frames together relatively easy. It also means the highest resolution part of the lens is used to form the majority of the completed image and if there's a bad frame you can almost completely remove it by masking in the neighbouring frames.

Armed with the focal length and overlap factor, you can calculate how many degrees to turn the camera. The first step to doing that is to calculate the field of view using the following formula:

$$\alpha = 2 \arctan \frac{d}{2f}$$

In this, α is the angle of the field of view, d is the sensor size (remember to calculate horizontal and vertical separately) and f is the focal length of the lens. The table (above right) shows the field of view that different focal lengths provide with a 35mm sensor, calculated using the formula. Finally, to calculate the angle to turn the camera between shots, you'll need to take the amount of each image that isn't an overlap and multiply that by the field of view. For a 24mm lens with a 30 per cent overlap,

	FIELD OF VIEW	
Focal length	**Horizontal**	**Vertical**
14mm	104°	81°
16mm	98°	74.1°
17mm	93°	70°
20mm	84°	62°
24mm	74°	53°
28mm	65°	46°
35mm	54°	38°

the amount of each image that isn't overlapped is 70 per cent, so (1 – 0.3) x 74 = 51.8° for the horizontal, and that (1 – 0.3) x 53 = 37.1° for the vertical.

To make sure that you can capture all your images within 20 minutes, you now need to calculate the number of images in rows and columns. If you have an automated panoramic head, your camera will be in landscape mode, so: 360÷51.8 = 7 frames for the horizontal. Then for the vertical, it's: 180÷37.1 = 4.8 frames, which you can round up to five. That's a total of 7 x 5 frames, which is 35 photographs. Using the 500 Rule you can work out you want a 20-second exposure from the 24mm ▸

STUART MCINTYRE X 2

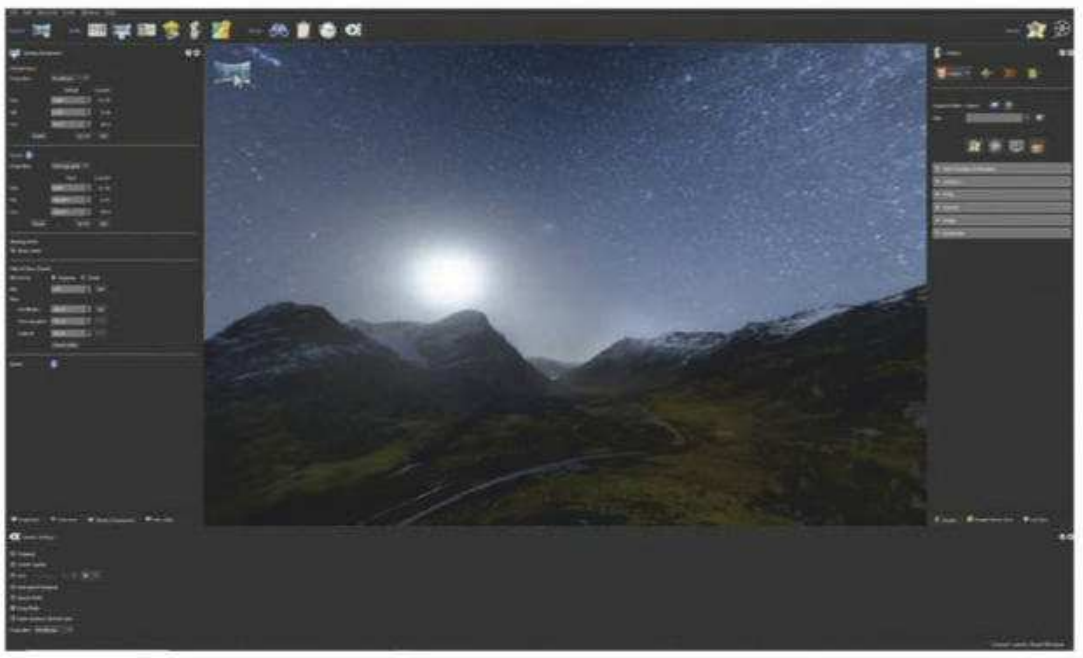
A panoramic image showing the Milky Way arching over the horizon

"To get the best results you need to take non-parallax images, where there's no perspective change"

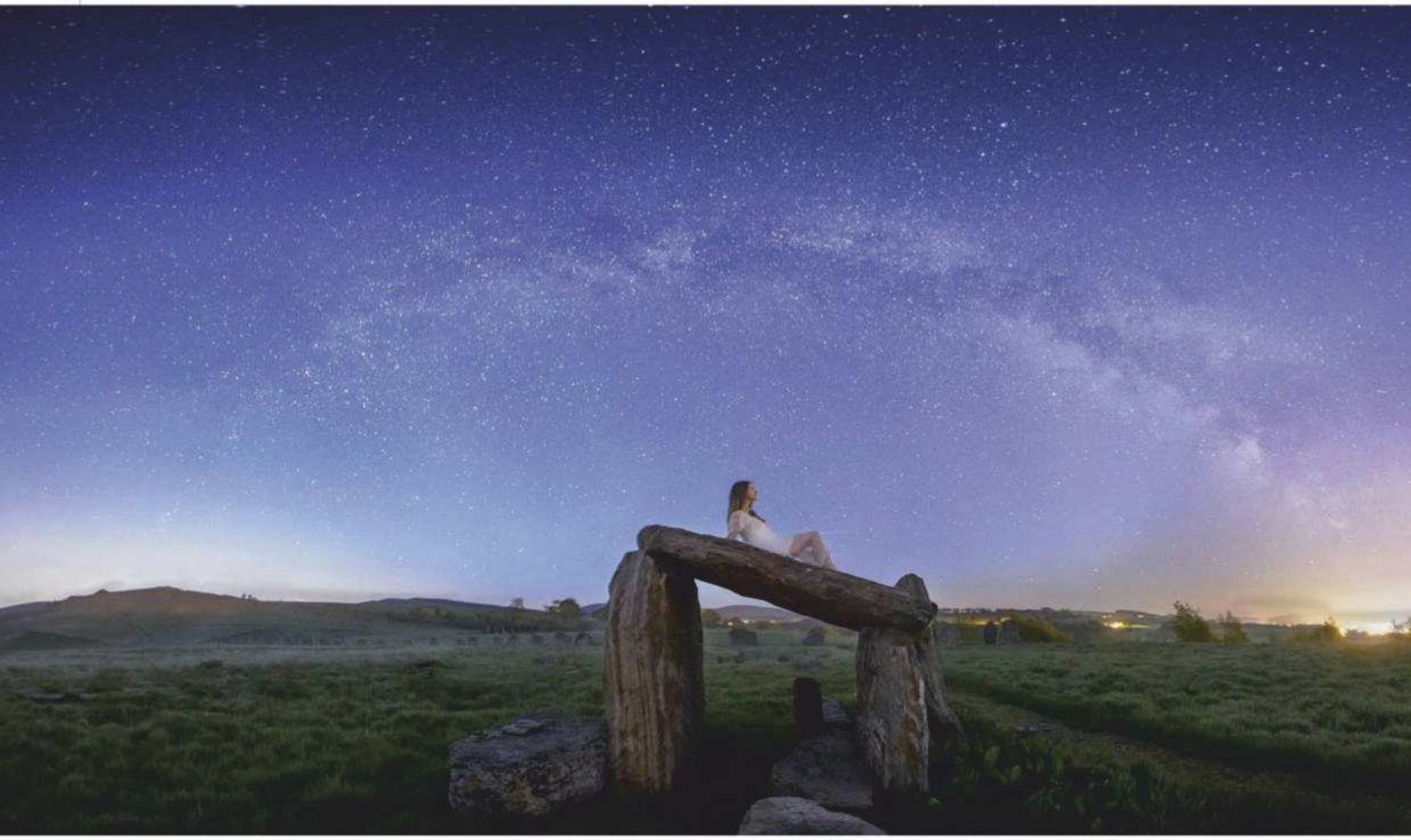
After the shoot

Plug your photos into the right software and you and your friends can explore the panorama you've created

Once you've captured your images and constructed your panorama you will want to show it off to the world, or at least publish it in a way that you and your friends can appreciate. So how do you do that? Owing to the fact that you'll have been trying to eliminate stereoscopic effects, virtual reality headsets will work but they won't give a truly immersive experience. Facebook and Google Maps are great platforms to show off your 360° image, though. To make the most of them, make sure your image is in a 2:1 ratio (600 x 3,000 is my preferred resolution); this will automatically be identified as it is uploaded to Facebook. Alternatively you can display your image on your own platform. There is a useful program called pano2VR by which to do this. Pano2VR will take your image and render it into a 3D sphere as well as offering you various editing options that are similar to PTGui panorama stitching software (see page 84). You can also create a webpage that can use QuickTime VR, HTML5 or Flash plugins.



▲ **Pano2VR provides a suite of editing features for your panoramic image**



▲ **Covering all points of the compass lets you see your image in the same way as you would in real life, although the effect is lost in 2D**

▸ lens, which means a total exposure time of just under 12 minutes, or 24 minutes with dark frames. Therefore photographing the rows first is important in some cases to avoid the stars shifting positions when you're stitching the images together.

The practice

That's the theory of panorama imaging taken care of; now it's time to start talking about equipment. A tripod is essential and it's important that you level off its legs perfectly, as any tilt on the horizon of images for a panorama has a very disorienting effect when you're stitching them together. If you don't want to invest in a panoramic head, good results can be achieved with a geared tripod head and a right-angled bracket. With these tools, the challenge is to minimise the movement of the objects in view: as you move your camera, objects at different distances will move different amounts. So compose your image without any objects in the

Panoramic heads – auto vs manual

If you want to get a panoramic head it's worth considering if you want an automated one or a manual one

Auto head

Advantages

▷ Will automatically calculate best procedure

▷ Can be left unattended or triggered

Disadvantages

▷ Heavy and awkward to transport

▷ Batteries very susceptible to cold conditions

STUART MCINTYRE X 5

Manual head

Advantages

▷ Light and easy to pack

Disadvantages

▷ You have to stand by it throughout the capture period

▷ You need Allen keys to change the degree it will turn

▼ **Movements and perspective changes during shooting will show up as stars appearing in multiple positions**

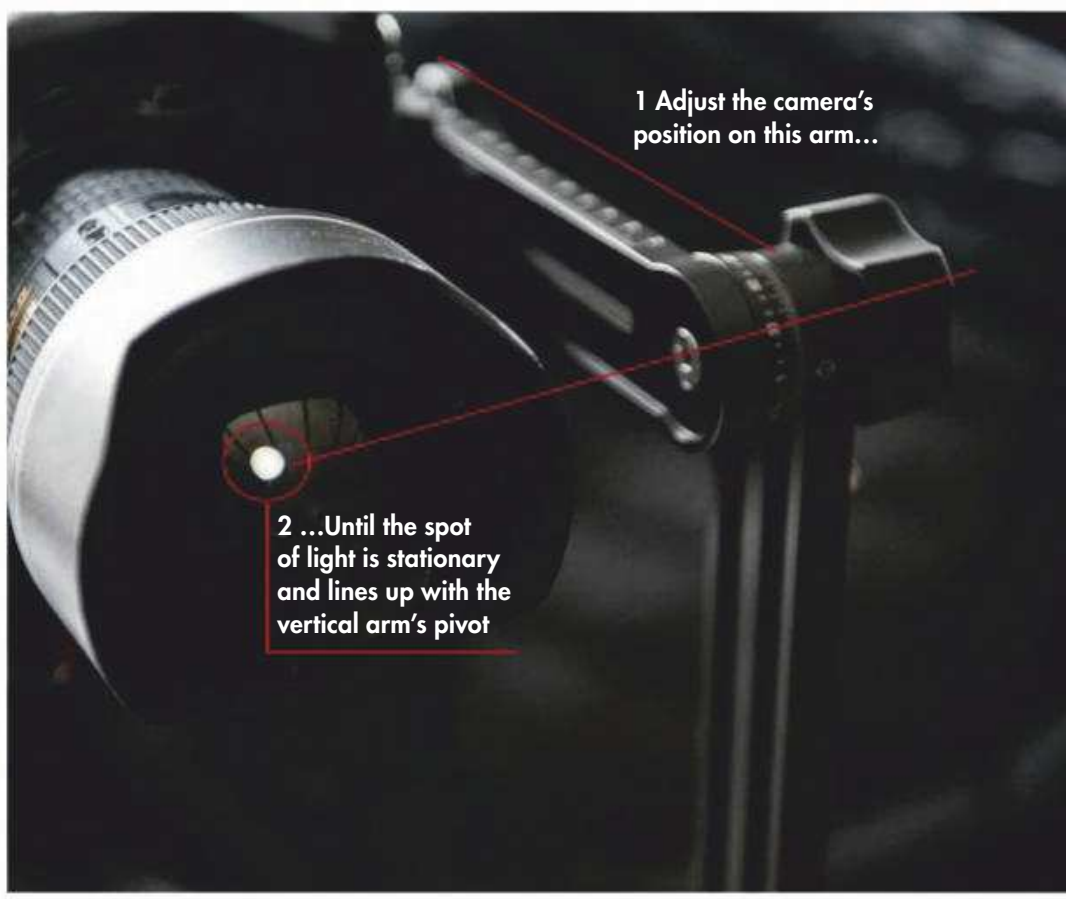
close foreground. Also use a large overlap and set your tripod as tall as possible. The picture above is an example of a panoramic image that I didn't merge because, if you look closely, you can see that the stars are being repeated in different locations.

Panoramic heads, whether they're manual or automatic, are designed to avoid parallax, an effect that's similar to seeing the world in stereoscopic vision with a pair of human eyes. In the same way that objects seem to move in relation to each other as you move your head, by moving your camera it can 'see around' objects and won't produce the same photo. To set up non-parallax imaging you need to find the nodal point of a lens. Finding the horizontal nodal point is quite simple. Set the camera so the autofocus is on the central focus point, then set up your panoramic head so that the camera is pointing straight down towards the central point of the tripod. Now adjust the camera so that the centre of the tripod is in the centre of the image. You should then be able to rotate the camera and not see the centre move off the focus point.

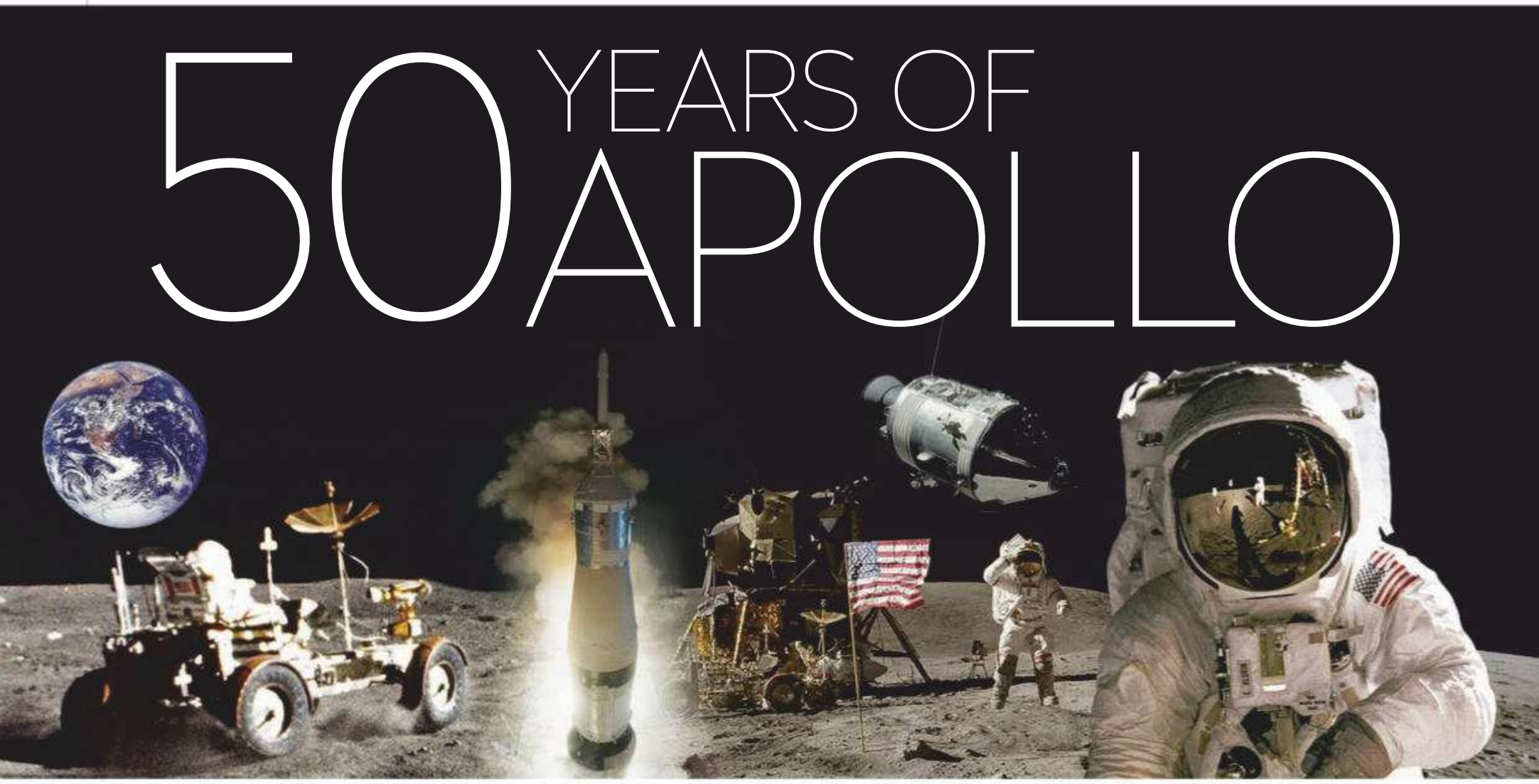
To set the vertical nodal point, place the camera so that strong window light enters the lens. Go to the front of the camera and look at the lens; you should see a bright spot. Move the camera using the vertical arm and the spot in the lens will move. Start adjusting the camera's position on the vertical arm until the point of light in the lens is stationary, then set the camera to f/16 and hold the preview depth of field button and the point will become smaller. This will allow you to fine tune and check the horizontal axis. Bear in mind that if you are using a zoom lens the nodal point will change.

I hope this article has inspired you to try panoramic imaging and armed you with the knowledge you need. Due to the number of aspects involved, it's a bit like learning to ride a bike and it's not going to work every time at first. But once you've done a few times it will become much more intuitive.

Turn to our Image Processing section on page 84 to find out how to process your 360° image to create a seamless final panorama



◄▲ **You'll need to set the camera's horizontal (left) and vertical (above) nodal points before embarking on a panoramic imaging session**



APOLLO 8

The first mission to the Moon changed how we looked at Earth forever. **Elizabeth Pearson** tells the story of the first manned lunar return

Although 21 December 1968 was the shortest day of the year, for the astronauts of Apollo 8 it would be one of the longest of their lives. The three men started it sitting on top of an untested rocket about to travel further from Earth than any human had been before. They were destined for the Moon.

But Apollo 8 wasn't originally intended to go that far. The mission brief was initially to stay in low-Earth orbit and practise manoeuvring with a lunar lander. By June 1968, however, it had become apparent that the lander wouldn't be ready in time for the mission's launch.

The timeline to meet the 1969 deadline for a lunar landing was already tight – a delay to Apollo 8 would derail it entirely. To avoid wasting the mission, NASA considered bringing forward the Apollo 9 mission plan and sending Apollo 8 to orbit around the Moon. It was an outrageous suggestion – only one Apollo mission had flown with a crew and the Saturn V rocket they planned to use on 21 December had never been launched with humans on board. Was it really a good idea to send astronauts to the Moon as the rocket's first big test?

Ultimately, the decision was made not by NASA, but by the Soviet Union. In September, the Russians launched Zond 5, sending the first living creatures (including a pair of tortoises) to the Moon and back. It seemed a crewed Soviet mission couldn't be far behind. With public support for Apollo already strained, NASA could not afford to be beaten by the Russians again. Apollo 8 was in a race to the Moon.

Three months later, the Apollo 8 astronauts were strapped into the Command Module waiting to launch. When the countdown hit zero, the crew began to fear that something might be wrong – the entire spacecraft was shaking like a freight

MISSION BRIEF

Launch date: 21 December 1968
Launch location: Launch Complex 39 A
Lunar orbits: 10
Lunar orbital altitude: 111km
Mission duration: 6 days, 3 hours and 42 seconds
Return date: 27 December 1968
Main goals: Demonstrate translunar injection; test navigation, communications and mid-course corrections; refine systems and procedures for future lunar operations
Firsts: Crewed flight around the Moon; crewed flight across Van Allen belts; live TV broadcast from lunar orbit
Christmas menu: Turkey, stuffing, cranberry, gravy, brandy (left unopened)

NASA X 10

THE ASTRONAUTS

Commander: Frank Borman
Borman joined NASA in 1962 from the air force and flew on the 14-day Gemini 7 mission. After Apollo 8, he was offered command of the first lunar landing but felt little enthusiasm for spaceflight, having only joined NASA to "beat the damn Russians" and left the agency. He worked for Eastern Airlines before retiring in 1986.

Command Module pilot: James 'Jim' Lovell
A navy test pilot before joining NASA in 1962, Lovell first flew in space on Gemini 7 with Borman. After Apollo 8, he was part of another Moon mission as part of the ill-fated Apollo 13 crew. He left the space programme in 1973 and worked in the corporate world, retiring in 1991. He still travels around the world giving speeches about his experiences.

Lunar Module pilot: William 'Bill' Anders
Originally an air force pilot, Anders had degrees in both electrical and nuclear engineering. He joined NASA in 1963 in the third group of astronauts. Apollo 8 was his only trip to space, though he retained his astronaut status while working for the National Aeronautics and Space Council. He went on to work in the field of nuclear energy.

The Saturn V rocket blasts off carrying the Apollo 8 astronauts into Earth orbit

"The Earth from here is a grand oasis in the big vastness of space." – Jim Lovell

train. In truth, the rocket was working perfectly; it was simply that the crew was unprepared for the sheer violence of lifting off in the world's most powerful rocket. The first stage blasted the crew to seven times the speed of sound, before the second and third stages took them into a parking orbit around Earth, 11 minutes and 34 seconds into the flight. But there would be no time for the crew to recover. They spent the next few hours checking the spacecraft before receiving the message, "Alright, Apollo 8. You are go for TLI [translunar injection]."

The crew fired the single engine in the third stage for 12 minutes and from then on there was no turning back.

► The Apollo 8 astronauts leave the crew quarters to board the module on top of the Saturn V rocket

As they travelled towards lunar orbit 385,000km away, the crew performed the procedures future lunar missions would need to carry out during their journeys. First, they set the spacecraft into a 'barbeque roll' to make sure the Sun didn't cook one side while the other froze in shadow. Then, though Apollo 8 didn't have a lunar lander on board, the crew performed a dry run of the manoeuvres needed to remove one from its housing behind the main command module.

Going silent behind the Moon

On Christmas Eve, three days after its launch, Apollo 8 reached its destination, successfully carrying humans closer to the Moon than ever before. Finally, the US had beaten the Soviets to a major lunar milestone.

It would have been possible for the crew to simply loop around the Moon and come straight back to Earth. But since the mission was running smoothly (bar a case of space sickness on the part of Commander Frank Borman), the order was given to enter lunar orbit.

The crew now had to fire the service module's engine for exactly the right amount of time. If the manoeuvre went wrong they could end up drifting irretrievably away into deep space. To make matters even more nerve wracking, the burn had to happen while they were on the far side of the Moon, where they would be out of contact with Earth.

Command Module pilot James Lovell told ground control: "We'll see you on the other side," and the ►

▲ William Anders took the famous photo that came to be known as 'Earthrise'

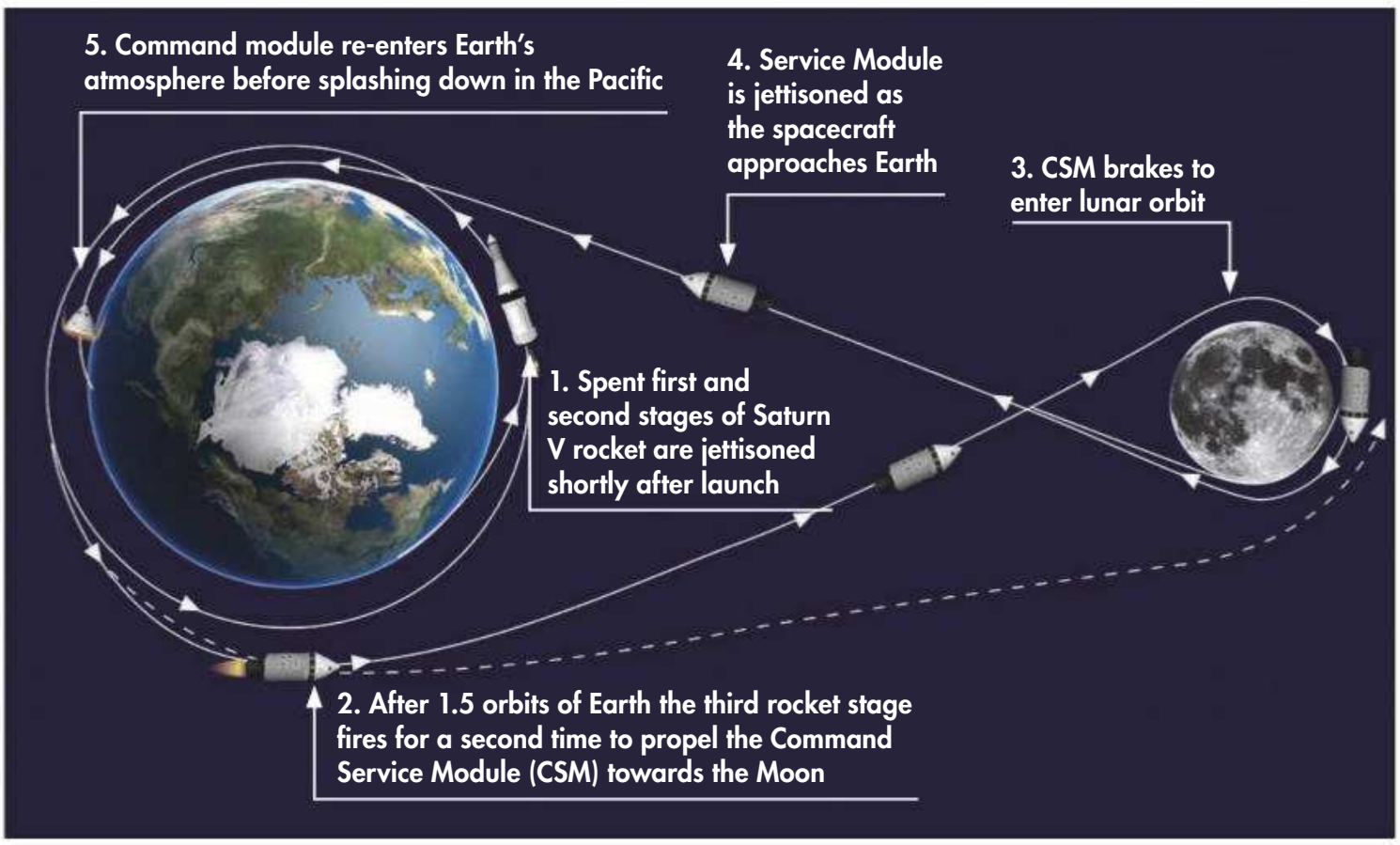
► crew performed their final checks before burning the engines for four minutes and seven seconds.

"Longest four minutes I ever spent," said William 'Bill' Anders as they waited for the timer to count down. But when the crew re-emerged from radio silence, they were in lunar orbit.

For the next 20 hours the crew's main task was to image the lunar surface, particularly the five spots NASA had lined up as potential landing sites for future Apollo missions. As they looked at the landscape they had come so far to see, Lovell and Anders were captivated by its expansiveness and stark contrasts. Borman, however, was less taken by the scene.

"My own impression is that it's a vast, lonely, forbidding type existence… It certainly would not appear to be a very inviting place to live or work," he said during a live television broadcast.

But as the crew emerged from behind the Moon for the fourth time, they were treated to a sight



NASA X 5, ILLUSTRATION BY PAUL WOOTTON

◄ Apollo 8's flightpath took the crew on a figure of eight path to and from the Moon

MISSION TIMELINE

21 Dec 12:51 GMT
The Saturn V carrying Apollo 8 launches from Cape Kennedy.

21 Dec 13:02 GMT
Apollo 8 enters Earth orbit.

21 Dec 15:18 GMT
After 1.5 orbits of Earth, Apollo 8 receives permission to go for translunar injection.

21 Dec 15:41 GMT
The S-IVB stage starts its burn, sending Apollo 8 towards the Moon. Six minutes later, translunar injection is achieved.

24 Dec 09:49 GMT
Apollo 8 approaches the Moon and disappears around its far side, losing contact with Earth.

24 Dec 09:59 GMT
The crew burn the engines for four minutes to enter lunar orbit.

25 Dec 02:34 GMT
Apollo 8 broadcasts its Christmas message.

25 Dec 06:10 GMT
An engine burn sets the spacecraft on a course back towards Earth.

27 Dec 15:37 GMT
The spacecraft re-enters Earth's atmosphere.

27 Dec 15:51 GMT
Apollo 8 splashes down in the north Pacific Ocean.

> "Did you guys ever think that one Christmas you'd be orbiting the Moon?"
> – Jim Lovell

that managed to break through even Borman's apparent apathy. "Oh my God!" he exclaimed. "Look at that picture over there! Here's the Earth coming up. Wow, is that pretty?!"

A new perspective on home

The globe of Earth floated in the darkness, the only point of colour in an infinite Universe of black and grey. Anders frantically searched for some colour film and took what would go on to be one of the most iconic photographs of all time: 'Earthrise'.

"The vast loneliness up here of the Moon is awe-inspiring," said Lovell during one of the Apollo 8 mission's six live television broadcasts. "It makes you realise just what you have back there on Earth."

One of the live television broadcasts the crew made while at the Moon fell on Christmas Eve. NASA predicted the historic transmission would reach the largest audience ever assembled and tasked the crew to do something appropriate. With the TV camera pointed out of the module's window, looking at the lunar landscape slowly rolling past, the crew took turns reading from Genesis, about the creation of the planet they could see floating in the black void of space.

▲ **Top: Frank Borman at work in the tight confines of Apollo 8's command module**
Above: Jim Lovell makes minor adjustments to Apollo 8's trajectory using the spacecraft's thrusters

"We came all this way to explore the Moon," William Anders said after the mission's successful return, "And the most important thing is that we discovered the Earth."

ABOUT THE WRITER
Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

▲ **The Apollo 8 crew scouted and imaged the lunar surface for possible landing sites for future missions**

▲ **Seeing Earth in the blackness of space had a profound effect on the crew of Apollo 8**

Astronomically accurate

A watch renowned for its peerless technicality - the precision of its JJ04 module can ensure the moon passing across its dial is accurate to a day every 128 years - as much as the lyrical beauty of its dial, the Moonphase now inherits our sleek new Grand Malvern case. With its subtle 'lightcatcher lines', the C1 Grand Malvern Moonphase is just as graceful as our lunar neighbour.

Do your research.

Christopher Ward

christopherward.co.uk

The Sky Guide December

The Geminid meteor shower peaks on the night of 13/14 December and the waning crescent Moon sets early enough for us to enjoy the spectacle in dark skies

GET THE SKY GUIDE WEEKLY

For weekly updates on what's best to observe, sign up to our email newsletter: **www.skyatnightmagazine.com/iframe/newsletter-signup**

ABOUT THE WRITERS

PETE LAWRENCE

Pete Lawrence is an astronomer and astro imager who presents *The Sky at Night* monthly on BBC Four

Stephen Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 60

RED LIGHT FRIENDLY

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

DON'T MISS...

- ✦ Naked eye comet 46P/Wirtanen makes a dash for it
- ✦ Mercury and Jupiter put on a show in the dawn sky
- ✦ The Moon buzzes the Beehive Cluster

DECEMBER **HIGHLIGHTS**

Your guide to the night sky this month

MONDAY
3

Early risers will be greeted by the sight of the 17%-lit waning crescent Moon forming part of a right-angled triangle with mag. –4.6 Venus and mag. +1.0 Spica (Alpha (α) Virginis), the star marking the right-angle. Catch them after 05:00 UT, low in the southeast.

WEDNESDAY
5

If you grabbed a view of the waning crescent Moon near Venus on 3 December, that was good training for this morning's encounter between a slender, 4% waning lunar crescent and mag. +0.9 Mercury. Catch them around 70 minutes before sunrise, low in the southeast.

THURSDAY
6

Tonight and into tomorrow morning comet 46P/Wirtanen will be located less than a degree from mag. +3.9 Eta (η) Eridani. The comet moves from a position southwest to northwest of the star throughout the night.

WEDNESDAY
12

This evening and into tomorrow morning, comet 46P/Wirtanen – brightening hopefully – passes approximately 1° to the east of two close stars in Taurus, mag. +3.6 Omicron (ο) and mag. +3.7 Xi (ξ) Tauri.

THURSDAY ▶
13

Tonight sees the peak of the Geminids. An early waxing Moon will set around 22:00 UT leaving the rest of the night good and dark to enjoy the show.

SATURDAY
15

Mag. –0.3 Mercury is currently visible low in the southeast before sunrise. Today the planet reaches greatest western elongation, when it will be separated from the Sun by 21.3°.

FRIDAY
21

A 95%-lit waxing gibbous Moon appears centrally within the V-shaped Hyades cluster and 2° from Aldebaran (Alpha (α) Tauri) at 05:00 UT.

The Northern Hemisphere's winter solstice occurs at 22:23 UT.

PETE LAWRENCE X 8

SATURDAY
22

Tonight is the peak of the Ursid meteor shower, but a full Moon will somewhat spoil this year's display.

SATURDAY ▶
29

Look out for mag. +8.9 dwarf planet Ceres, 3° north of mag. –4.4 Venus.

6 Hebe reaches opposition in Monoceros. The mag. +8.4 asteroid is 3° west of NGC 2244, the central cluster of the Rosette Nebula.

FRIDAY ▶ 7

Locate mag. +0.1 Mars after the sky has darkened and take a look at it through binoculars or a small telescope. Mag. +7.9 Neptune is located just 8 arcminutes to the southwest of Mars (below and right as seen from the UK).

MONDAY 10

This evening and into the morning of 11 December, comet 46P/Wirtanen passes approximately 4° east of mag. +2.5 Menkar (Alpha (α) Ceti).

FRIDAY ▶ 14

This evening, the 44% waxing crescent Moon lies 4.6° south of mag. +0.2 Mars. A telescopic view of the Moon from 21:00 UT reveals the clair obscur effects known as the Lunar X and Lunar V. They'll be at their best around 21:50 UT.

◀ SUNDAY 16

This morning and over the course of the next day, comet 46P/Wirtanen will pass between the Pleiades and Hyades open clusters in Taurus. The comet will pass the Pleiades by around 4°.

TUESDAY 18

This evening and through to the morning of 20 December, comet 46P/Wirtanen will be passing approximately 6° east of NGC 1499, the California Nebula. A bright Moon will hamper views. The comet is closest to Earth today, passing us by 11.8 million km.

THURSDAY 20

Mag. −0.4 Mercury is 1.8° from mag. −1.6 Jupiter this morning. Visible low in the southeast approximately 80 minutes before sunrise, the planets appear even closer at just 1° apart on 21 and 22 December.

SUNDAY 23

Comet 46P/Wirtanen passes less than a degree east of Capella (Alpha (α) Aurigae) this evening and into tomorrow morning.

◀ TUESDAY 25

This morning, a bright 91%-lit waning gibbous Moon passes 1° to the south of the Beehive Cluster, M44, which lies at the heart of Cancer, the Crab. The closest approach is around 05:30 UT.

FAMILY STARGAZING – ALL MONTH

There's a chance that comet 46P/Wirtanen will be a naked-eye object throughout December. If it is, then its favourable position makes it a great target for youngsters to look for. The comet passes closest to Earth on 18 December but a bright Moon will interfere with the view at this time. The best periods to look for it will be at the beginning and end of the month (see page 52). The unpredictable nature of comets means that it is probably a good idea to have binoculars on hand, just in case it fails to become bright enough to be seen with the naked eye.

www.bbc.co.uk/cbeebies/shows/stargazing

NEED TO KNOW

The terms and symbols used in *The Sky Guide*

UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (RIGHT ASCENSION) AND DEC. (DECLINATION)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'.

FAMILY FRIENDLY
Objects marked with this icon are perfect for showing to children

NAKED EYE
Allow 20 minutes for your eyes to become dark-adapted

PHOTO OPP
Use a CCD, planetary camera or standard DSLR

BINOCULARS
10x50 recommended

SMALL/ MEDIUM SCOPE
Reflector/SCT under 6 inches, refractor under 4 inches

LARGE SCOPE
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing a scope.

THE BIG **THREE**

The three top sights to observe or image this month

DON'T **MISS**

Comet 46P/ Wirtanen pushes north

BEST TIME TO SEE: 15-18 December

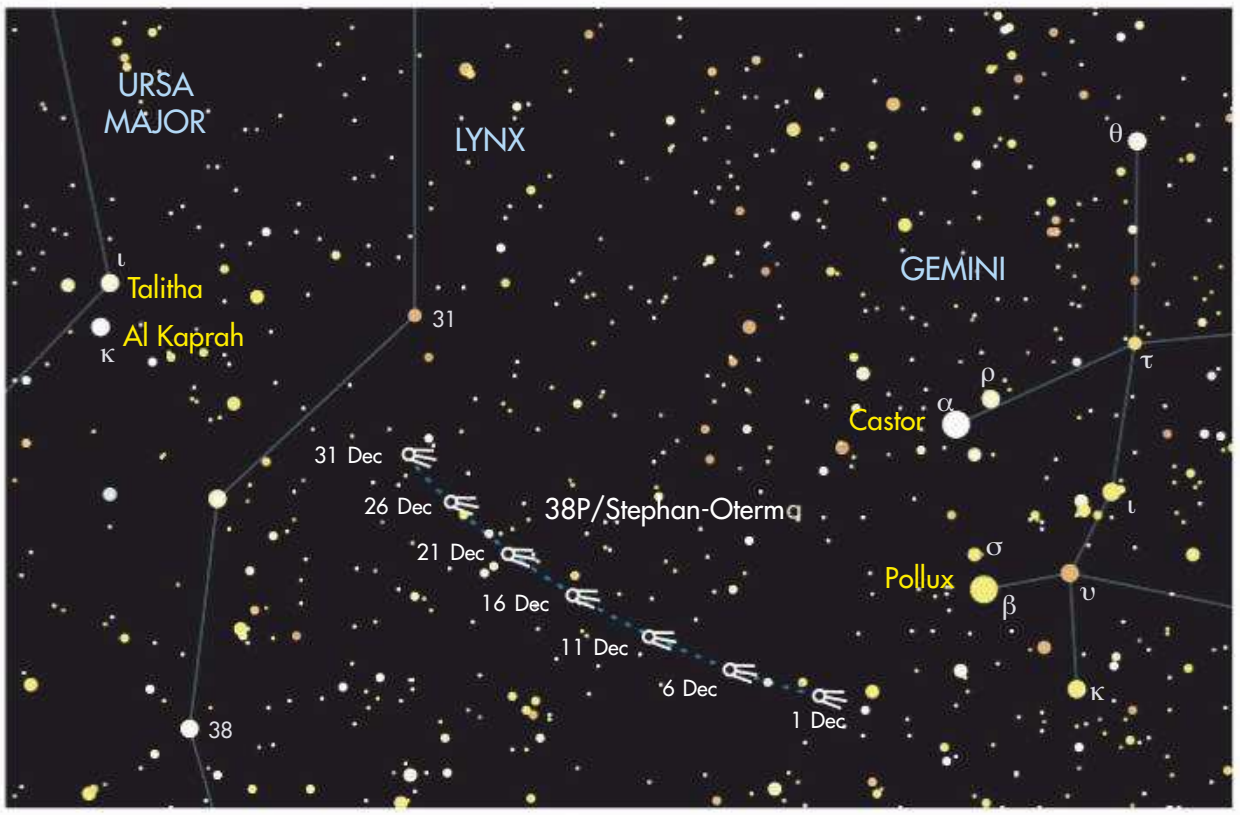
Comet 46P/Wirtanen passes relatively close to Earth during the middle of the month. Early predictions for Wirtanen had it peaking around 4th magnitude, making it an easy naked-eye object. More recent observations have tempered these expectations and Wirtanen may only reach mag. +5.5, barely scraping past the naked-eye threshold.

It's important when describing comets to keep an open mind. They may obey predictions or they may not. The only way to be sure is to go outside and have a look.

Wirtanen will pass our planet by 0.078 AU mid-month. This will also impact on its brightness because the head of the comet is likely to appear quite large and consequently of low surface brightness.

If this all sounds a little negative, it's not meant to. What's important when going outside to view 46P/Wirtanen is to have the right expectations, because 46P should still provide a number of interesting viewing and photographic opportunities. On the night of 9/10 December, for example, it'll be located approximately 8° northwest of mag. +7.7 minor planet 3 Juno. Between 15 and 18 December it'll pass between the Pleiades and Hyades open clusters. On the night of 23/24 December, it will be located very close to bright star Capella (Alpha (α) Aurigae), presenting an easy way to locate it.

▲ **The path of 46P/Wirtanen in December, when it won't quite be as bright as was predicted**



PETE LAWRENCE X 4

▲ **You'll need a telescope to spot 9th magnitude 38P/Stephan-Oterma as it heads towards Lynx**

The natural enemy of comets is the Moon, its light filtering out the diffuse detail in a comet's head and tail. During December, the Moon will interfere more towards the end of the month. The period 1-18 December should be fine and, as long as you're prepared to wait until the early hours for moonset, viewing through to 21 December should be possible. With careful planning, viewing early evening before moonrise from 24 December through to early January will mean you'll only lose sight of the comet because of the Moon for a couple of days.

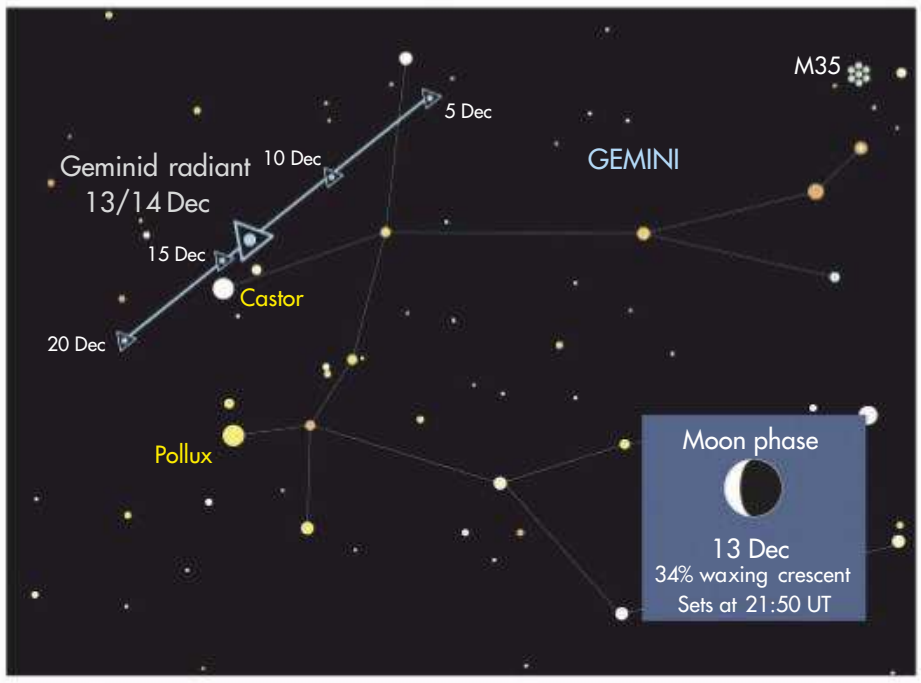
Wirtanen ends the month in the faint constellation of Lynx. By coincidence Lynx will also play host to another comet, 38P/Stephan-Oterma. This is expected to be fainter than 46P/Wirtanen, starting December at mag. +9.2 and ending it at mag. +9.9, so telescope friendly.

Geminids peak

BEST TIME TO SEE: Active from 4-17 December, peaks on 13/14 December

The Geminid meteor shower reaches peak activity on the night of 13/14 December. This is the most regularly active of all the annual meteor showers, with a Zenithal Hourly Rate (ZHR) of 120. The ZHR of a meteor shower is a normalised value indicating how many meteors you could expect to see under perfect skies with the radiant overhead and a view taking in the entire sky. The visual rate – that's the number of meteors you are actually likely to see – will always be lower.

For the Geminids, a peak UK visual rate of 50 meteors is reasonable to expect. Bear in mind the appearance of meteors will not be evenly distributed throughout the night. It's fairly typical to wait ages before seeing anything and then, just as you're about to give up, multiple trails appear and revive your interest.



▲ **Geminid meteors will appear to originate from somewhere near Castor**

The radiant for the peak period of the Geminids lies near to the bright mag. +1.6 star Castor (Alpha (α) Geminorum), which makes its position easy to visualise. For a meteor to belong to the Geminid shower, its trail must appear to originate from the radiant location.

Geminid meteors are mid-speed, entering Earth's atmosphere at 35km/s, making them reasonable candidates for meteor photography. This year a 34%-lit waxing crescent Moon sets around 21:50 UT on 13 December, leaving the rest of the night good and dark for meteor watching.

For the most comfortable experience, use a garden lounger arranged so you're looking up at an angle of around 60° (two-thirds up the sky from the horizon). Any direction is good, with the trails appearing longest at 90° from the radiant. Trails appear progressively shorter the closer they occur to the radiant. This is an effect of perspective.

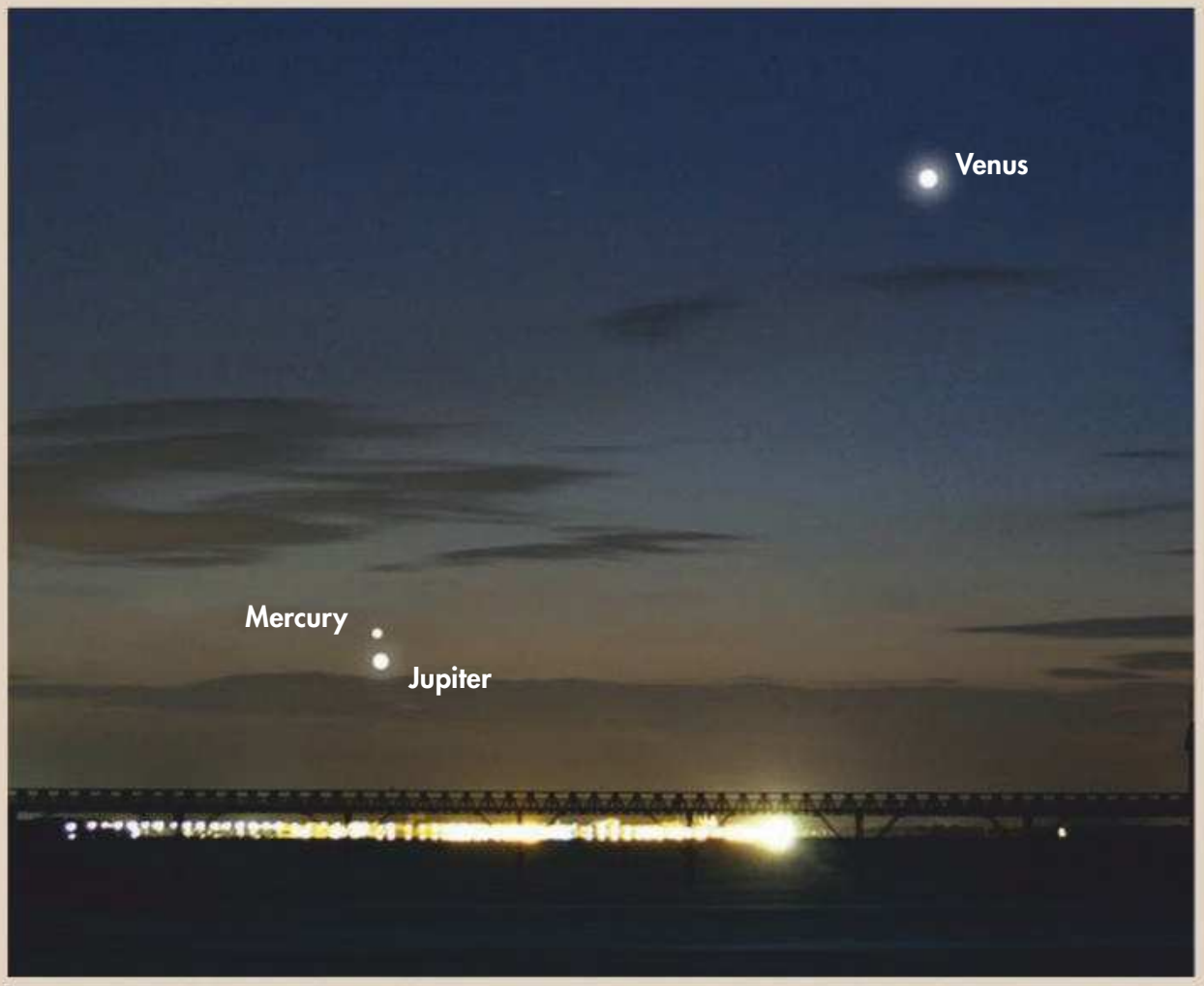
Morning planets

BEST TIMES: 3, 4 December for Venus-Moon conjunction; 21, 22 December for Mercury-Jupiter conjunction

Mercury, Venus and Jupiter all put on an early morning show during December. At the start of the month, it's 'Morning Star' Venus that dominates the scene, shining away at mag. –4.6, 6.2° from mag. +1.0 Spica (Alpha (α) Virginis). At this time Mercury and Jupiter will be too close to the Sun to be visible.

A slender 16%-lit waning crescent Moon sits 7.7° above and right of Venus on the morning of 3 December and as a 9%-lit crescent, 6.2° to the left of Venus on the morning of 4 December. The pair is best seen from 06:30 UT, low in the southeast.

You might catch a glimpse of mag. +0.9 Mercury on the morning of 5 December, the planet being located 7.6° below and left of a very thin 1%-lit waning lunar crescent towards the southeast on this date.



▲ **Mercury and Jupiter have a close approach just before sunrise on 21 and 22 December**

On the morning of 15 December, mag. –1.6 Jupiter can be seen with mag. –0.3 Mercury 6.3° above and to its right as seen from the UK. Over the following days both planets converge as Mercury slips ever eastward. On the morning of 21 December, now at mag. –0.4, Mercury sits 1° above Jupiter. A similar situation occurs on 22 December with Mercury now appearing to the left of Jupiter.

THE NORTHERN HEMISPHERE IN DECEMBER

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

- COMPASS AND FIELD OF VIEW
- MILKY WAY

WHEN TO USE THIS CHART

1 DECEMBER AT 00:00 UT
15 DECEMBER AT 23:00 UT
31 DECEMBER AT 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.

SUNRISE/SUNSET IN DECEMBER*

DATE	SUNRISE	SUNSET
1 Dec 2018	08:03 UT	15:55 UT
11 Dec 2018	08:16 UT	15:51 UT
21 Dec 2018	08:24 UT	15:52 UT
31 Dec 2018	08:26 UT	16:00 UT

MOONRISE IN DECEMBER*

MOONRISE TIMES

1 Dec 2018, 00:30 UT	17 Dec 2018, 13:30 UT
5 Dec 2018, 05:36 UT	21 Dec 2018, 15:15 UT
9 Dec 2018, 09:55 UT	25 Dec 2018, 19:30 UT
13 Dec 2018, 12:14 UT	29 Dec 2018, –:– UT

***Times correct for the centre of the UK**

LUNAR PHASES IN DECEMBER

SATURDAY	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
1	2	3	4	5	6	7 NEW MOON
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22 FULL MOON	23	24	25	26	27	28
29	30	31				

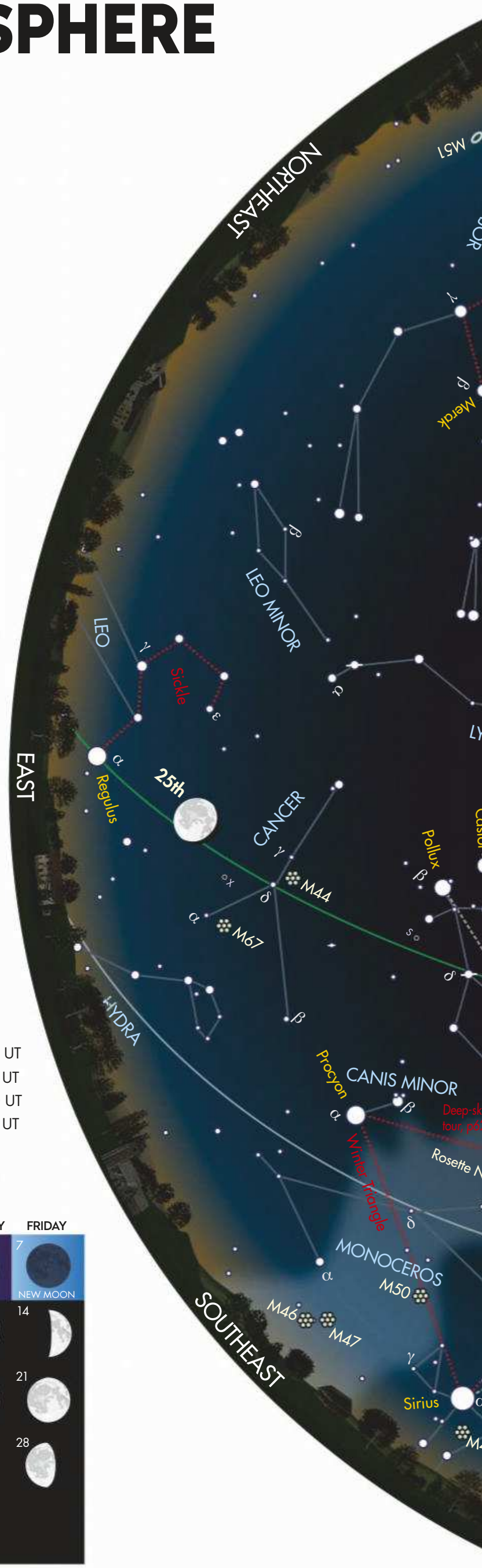
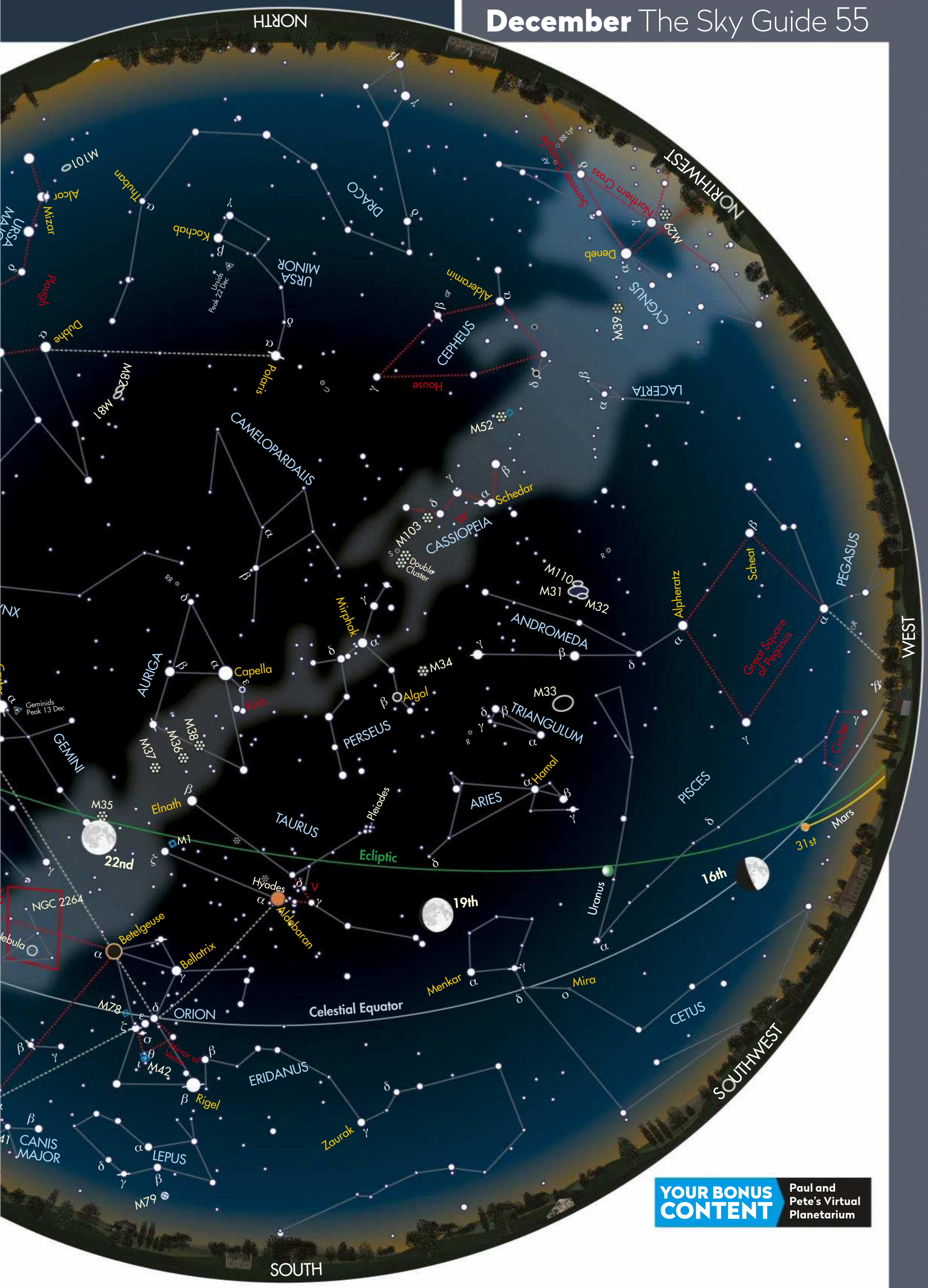


CHART: PETE LAWRENCE



YOUR BONUS CONTENT Paul and Pete's Virtual Planetarium

THE **PLANETS**

PICK OF THE **MONTH**

Mars

Best time to see: 1 December, 06:20 UT
Altitude: 28°
Location: Aquarius
Direction: South
Features: Polar caps, albedo markings, phase
Equipment: 28-inch or larger

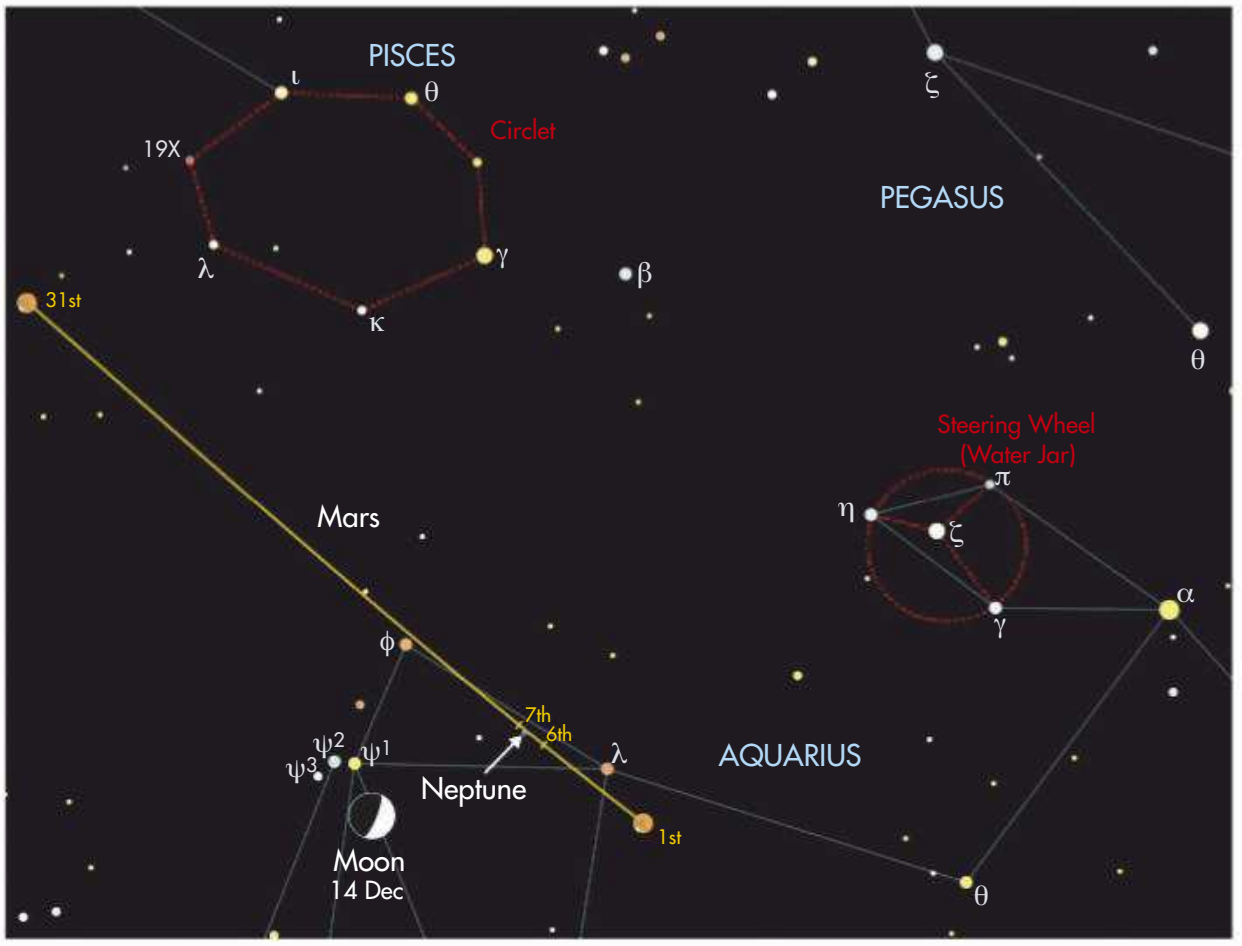
If there were ever an award for the most frustrating planet in the sky for UK observers, Mars would win it hands down. It reached a favourable opposition on 27 July of this year but from the UK this happened very low down in the south. This month, as the distance between Earth and the Red Planet increases, Mars starts to gain altitude – of course!

The increase in distance means that our view of Mars through a telescope now shows a much smaller disc – just 9 arcseconds across on 1 December, shrinking to just 7 arcseconds by the end of the month. Compared to the 24 arcseconds Mars presented back in July, it's now looking rather small.

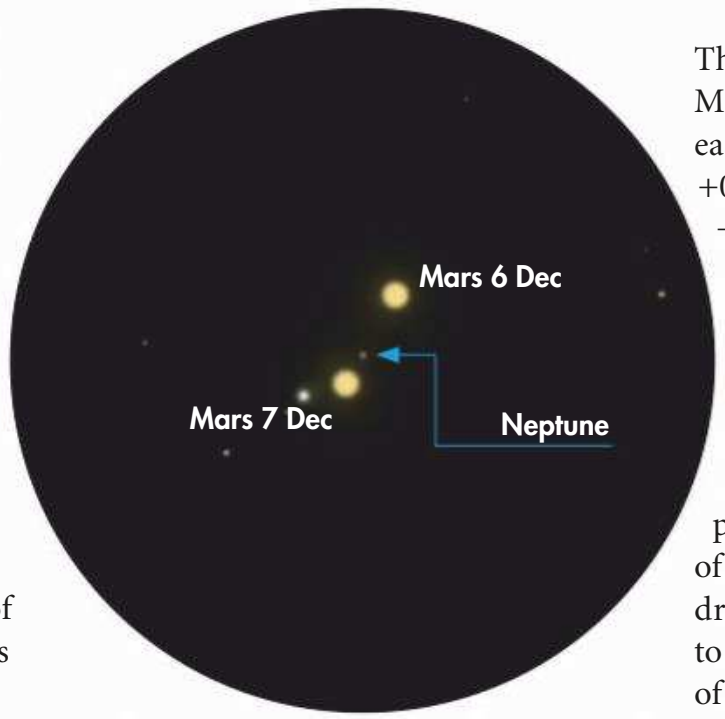
The Red Planet is currently an evening object in Aquarius. On 1 December it lies 2° southwest of mag. +3.7 Lambda (λ) Aquarii and shines at mag. 0.0. It passes 40 arcminutes south of Lambda on the evening of 4 December as it heads towards a close encounter with Neptune on 6 and 7 December.

On 6 December, mag. +0.1 Mars lies 27 arcminutes west of mag. +7.9 Neptune.

PETE LAWRENCE X 3



▲ **Mars's apparent size shrinks as it moves away from Earth, but at least it climbs higher in the sky**



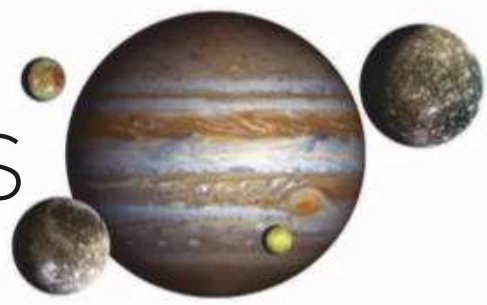
▲ **Mars will lie 27 arcminutes west of Neptune on 6 December, but the on the following night the two planets will have swapped sides**

The following evening the positions swap, Mars moving to a position 11 arcminutes east of Neptune. On 12 December, mag. +0.2 Mars lies 20 arcminutes from mag. +4.2 Phi (φ) Aquarii. A 43%-lit waxing crescent Moon sits near Mars on the evening of 14 December.

On 22 December, mag. +0.3 Mars slips across the border from Aquarius into Pisces and by the end of the month, it can be seen moving south past the Circlet asterism. By the end of December its magnitude will have dropped to +0.5. This is when it manages to attain a maximum altitude, due south, of 36° (just over a third of the way up the sky from the horizon) as seen from the centre of the UK. This is 3.6 times higher than it managed at opposition!

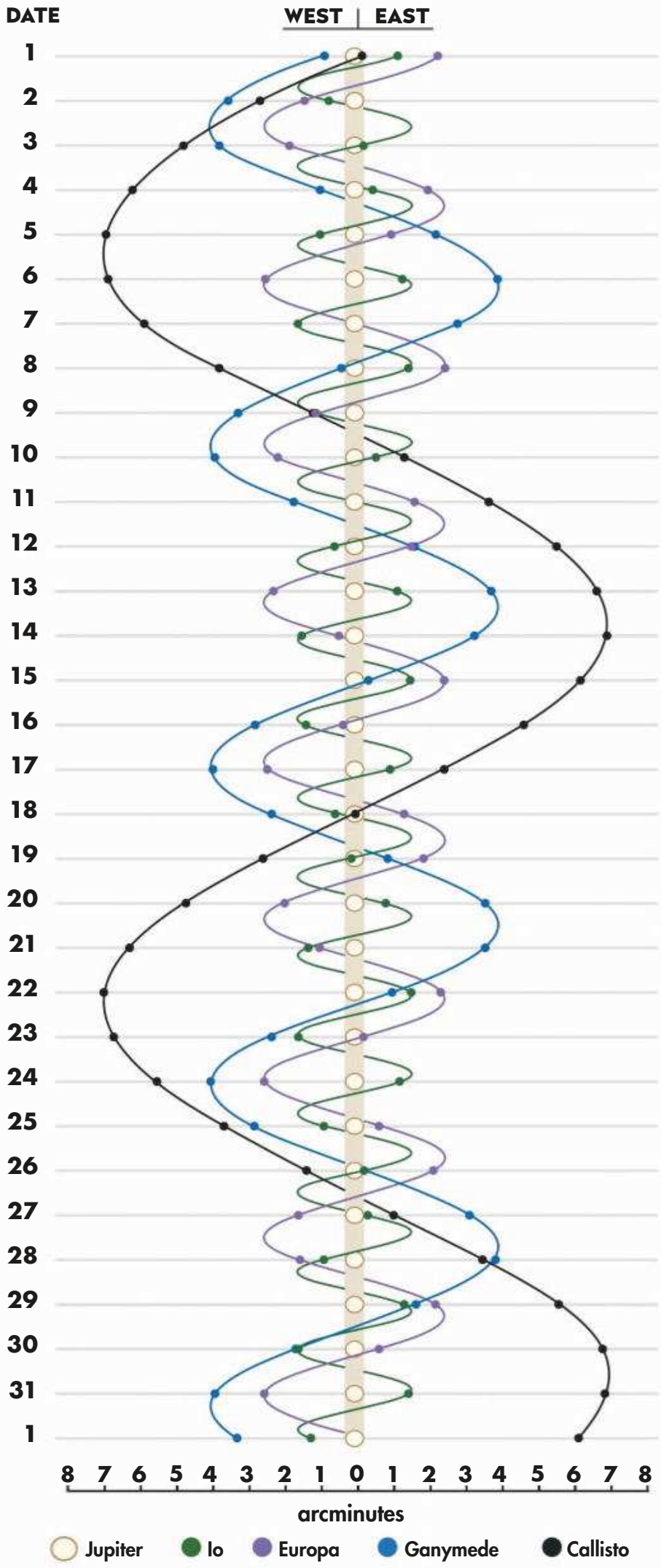
THE PLANETS IN DECEMBER

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



JUPITER'S MOONS DECEMBER

Using a small scope you'll be able to spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date on the left represents 00:00 UT.



Mercury

Best time to see: 21 Dec, one hour before sunrise
Altitude: 6° (low)
Location: Ophiuchus
Direction: Southeast

Mercury is in a good position in the morning this month. A 4%-lit waning crescent Moon sits 7.5° west of mag. +0.8 Mercury on 5 December. A telescope will show an 8 arcsecond, 23%-lit crescent on this date. Both phase and brightness increase as the planet moves towards greatest eastern elongation (21°) on 15 December when mag. –0.2 Mercury rises two hours before the Sun. On 21 December mag. –0.4 Mercury passes 1° from mag. –1.6 Jupiter, a situation repeated the following morning. At the end of the month mag. –1.6 Mercury rises above the southeast horizon about one hour before the Sun.

Venus

Best time to see: 1 Dec, 07:00 UT
Altitude: 20°
Location: Virgo
Direction: Southeast

Venus rises nearly four hours before the Sun. There's a lovely meeting between mag. –4.5 Venus and a waning crescent Moon on the mornings of 3 and 4 December. A telescope shows a 25%-lit crescent, 40 arcsecond across on 1 December. By the end of the month it appears 46% lit and 26 arcseconds across.

Jupiter

Best time to see: 31 Dec, one hour before sunrise
Altitude: 7°
Location: Ophiuchus
Direction: Southeast

Jupiter was in conjunction with the Sun on 26 November and this month returns to the morning sky. Look for an encounter with a less than 1%-lit waning crescent Moon on the morning of 6 December, the Moon lying 4° above Jupiter around 40 minutes before sunrise. On 21 December, mag. –0.4 Mercury appears 1° above mag. –1.6 Jupiter, low in the southeast around 07:00 UT. By 31 December, Jupiter will be trailing mag. –4.4 Venus as both planets climb into the morning sky.

Saturn

Best time to see: 1 Dec, 17:00 UT
Altitude: 5°
Location: Sagittarius
Direction: Southwest

Saturn is low on the southwest horizon at the start of the month but soon lost in the post-sunset glare. On the evening of 9 December it appears 5.3° west of a slender, 5%-lit waxing crescent Moon.

Uranus

Best time to see: 1 Dec, 23:20 UT
Altitude: 48°
Location: Aries
Direction: South

On 1 December, Uranus is in Aries, the Ram. By 3 December, it slips over the border into Pisces. The mag. +5.8 planet continues moving west until, at the end of December, it's 1.2° north of mag. +4.3 Omicron (o) Piscium. Uranus passes its highest point in the sky, due south, in darkness all month.

Neptune

Best time to see: 1 Dec, 18:30 UT
Altitude: 30°
Location: Aquarius
Direction: South

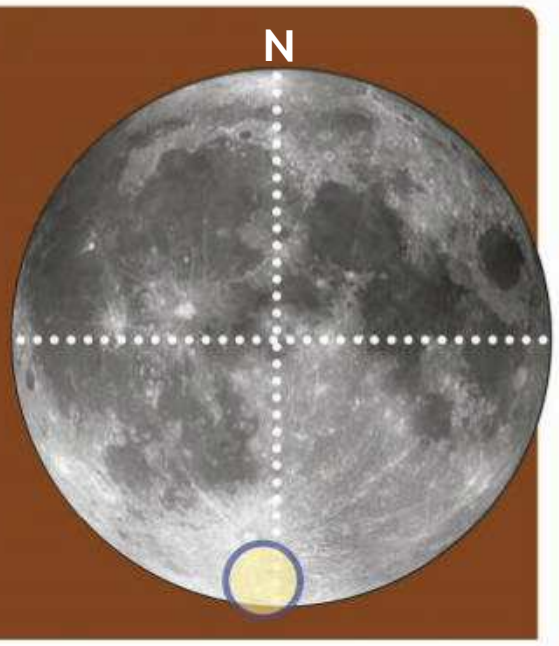
On the evening of 6 December, mag. +0.1 Mars is 0.5° west of mag. +7.9 Neptune. The following evening, Mars appears 7 arcminutes to the east. Neptune is well placed all month, passing 14 arcminutes to the south of mag. +6.2 81 Aquarii. However, it only reaches its highest position in the sky in darkness until 10 December. After this, Neptune slips ever westward, losing altitude each passing day as darkness falls.

YOUR BONUS CONTENT Planetary observing forms

MOON**WATCH**

Rutherfurd

Type: Crater
Diameter: 55km
Longitude/latitude: 12.2° west, 61.1° south
Age: Younger than 1.1 billion years
Best time to see: A day after first quarter (16 Dec) and a day after last quarter (1 Dec and 30 Dec)
Minimum equipment: 50mm binoculars



"There is a curious, curving progression of craters formed in different eras"

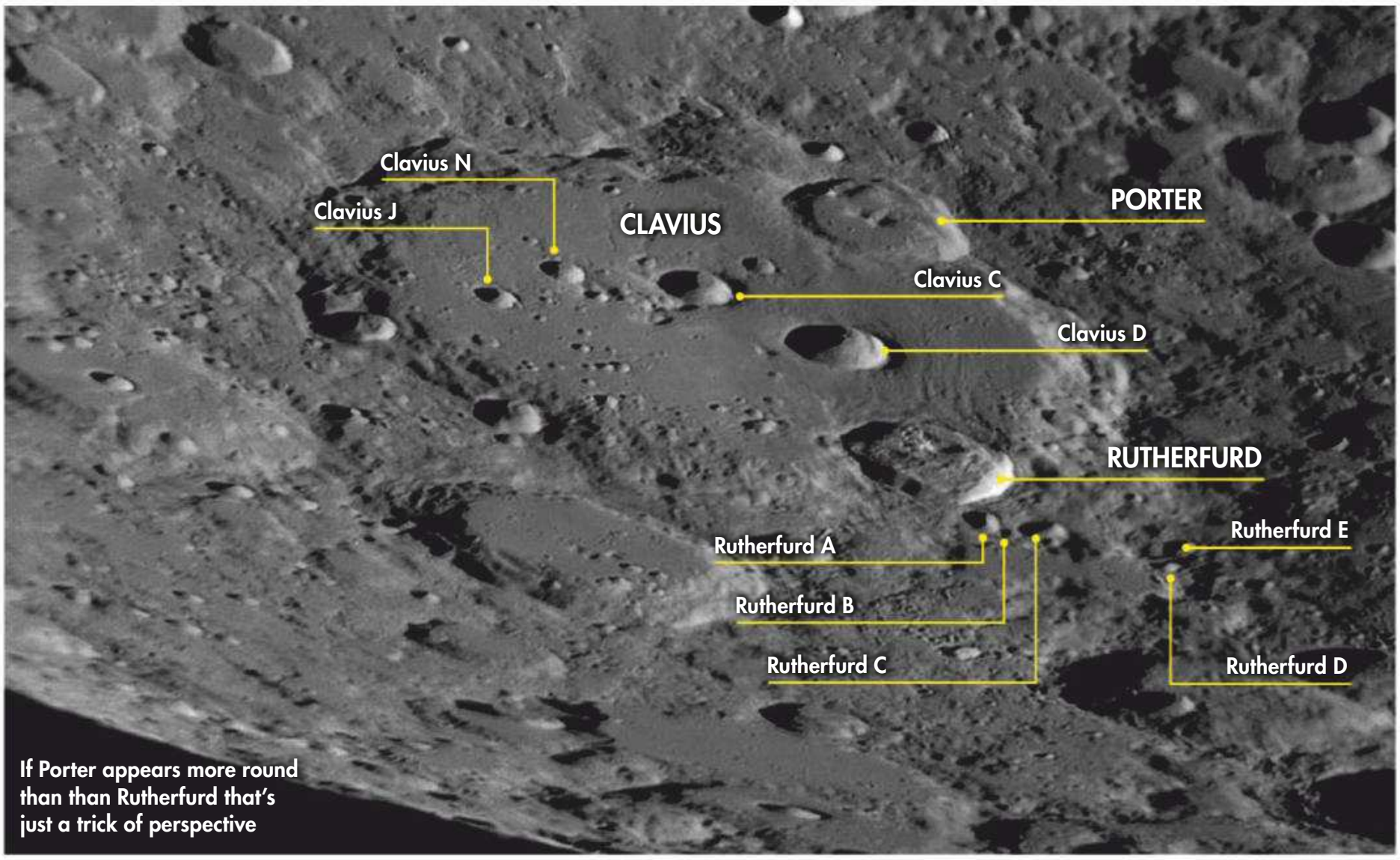
At 55km across, **Rutherfurd** isn't exactly a small crater. However, its location on the southeast rim of 225km **Clavius** tends to mean it's somewhat overlooked. Clavius is a favourite target for all sizes of telescope because it's large, easy to find and full of interesting detail. In particular there is a curious curving progression of craterlets, formed from impacts of different ages, starting at 12km **Clavius J**, moving onto 13km **Clavius N**, 21km **Clavius C** and 28km **Clavius D**. Rutherfurd ends the arc and its inclusion in what is essentially a craterlet sequence is probably another reason why it tends to be disregarded in favour of its larger host.

Rutherfurd is a well-defined, young crater named after Lewis Rutherfurd who took the first photographic images of the Moon through a telescope. The crater's sharp, crenulated, oval rim has a long axis orientated roughly north-south. It has a 1km high 'central' peak offset northeast of Rutherfurd's true centre. The rest of the floor has a level approximately 1km below that of Clavius. It appears quite rugged with small hills to the north and a larger more contiguous, wave-like region covering approximately one-third of the floor area towards the south.

Large smooth patches on Rutherfurd's floor are most likely the result of lava melt pools, regions where molten lava has flowed, levelled and cooled. The region to the north, and more particularly northwest, of the crater's 'central' peak is particularly bumpy with many small hills. These are easier to see when the lunar terminator is nearby.

To the south of Rutherfurd lie its allocated sub-craters; 10km **Rutherfurd A**, 6km **B**, 13km **C**, 9km **D** and 9km **E**. The region to the north is interesting because of the ejecta pattern that appears to extend north towards 53km **Porter**. This pattern takes the appearance of a number of shallow channels and bumps stretching northwards. The texture of the channels under high-resolution suggests they are made from closely overlaid craterlets. This is particularly evident along the channel that passes from Rutherfurd but is interrupted by Clavius D. These features are extremely narrow and best seen through large telescopes when the surface lighting is oblique.

Porter is another crater that interrupts Clavius's rim, this time to the northeast, mirroring Rutherfurd across the horizontal axis of the elliptical-looking Clavius. In reality Clavius is quite round, its elliptical appearance the result of foreshortening due to its proximity to the southern limb. The same effect adjusts our view of Rutherfurd and Porter, but as the latter is nearer the lunar equator, it appears less distorted and slightly larger. Porter is, in fact, a tad smaller than Rutherfurd.



If Porter appears more round than than Rutherfurd that's just a trick of perspective

PETE LAWRENCE X 3

COMETS AND **ASTEROIDS**

433 Eros is a large near-Earth object which may one day get very up close and personal

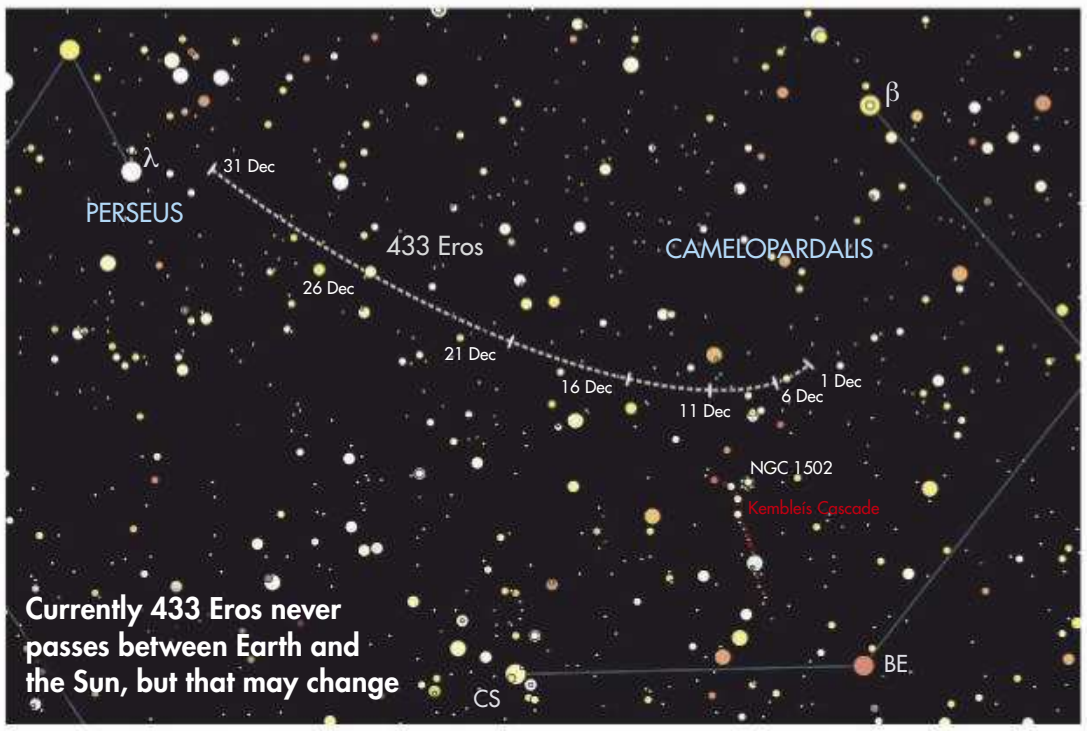
Minor planet 433 Eros is a siliceous or S-type asteroid, which means it has a stony composition. At 34.4x11.2x11.2km its elongated body is the second largest near-Earth object known. It belongs to a group of objects called the Amor asteroids, named after 1221 Amor. All the asteroids in this family have orbits that remain outside Earth's orbit.

Eros was the first asteroid to be orbited and landed on by a spacecraft. The craft in question was NEAR Shoemaker, which entered its orbit in 2000 and soft landed the following year.

Like most Amor asteroids, Eros's orbit crosses Mars's. At aphelion it is 1.78 AU from the Sun and at perihelion comes as close as 1.13 AU. At favourable oppositions – which occur every 81 years – Eros can appear as bright as mag. +7.0. This year, though, when Eros reaches opposition on 7 December, it will appear as a mag. +9.7 object in the ill-defined constellation of Camelopardalis. Its distance from Earth will be about 40.5 million km, which may sound close but is significantly further than our 26.7 million km close encounter with it on 31 January 2012.

It's thought that gravitational perturbations could alter Eros's orbit from a Mars-crosser to an Earth-crosser within a couple of million years. Eros is classed as a potential Earth impactor; worryingly it is five times the size of the asteroid that caused the extinction of the dinosaurs.

At the start of December, 433 Eros is located 2.5° east of the eastern end of the asterism Kemble's Cascade in Camelopardalis. It then arcs west as it heads south. Its distance from Earth continues to decrease during December, and so its apparent brightness increases. On 1 December, when Eros is 2.9 AU from Earth, it shines at mag. +9.9. By the end of the month its distance will drop to 2.2 AU and its magnitude will rise to +9.2.



STAR OF **THE MONTH**

Rigel, Orion's true alpha if not for a clerical error...

► Massive, bright, young and variable, Rigel is one of the most ostentatious stars in the sky

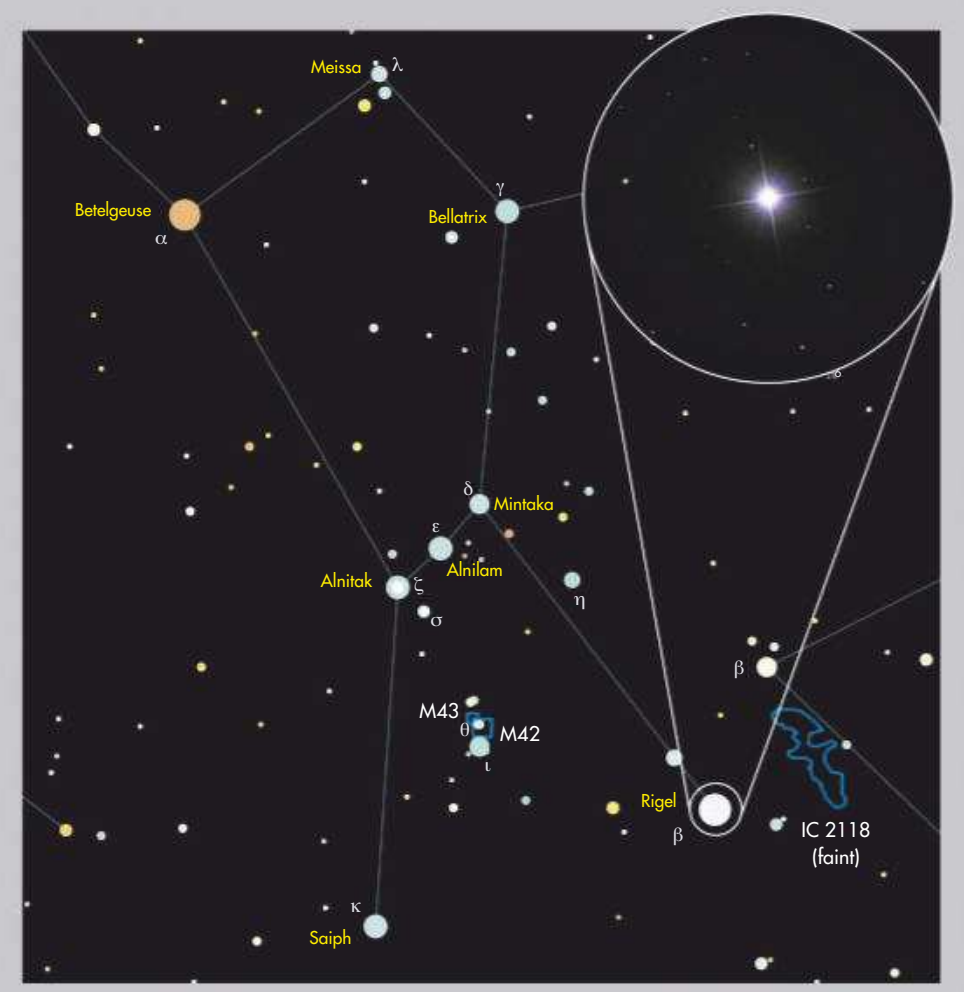
There are two famous supergiant stars in the main pattern of Orion. In the northeast corner lurks orange-hued Betelgeuse (Alpha (α) Orionis), a red-supergiant star coming to the end of its life. In the southwest corner is the blue-supergiant Rigel (Beta (β) Orionis).

Rigel represents Orion's foot – the name originating from the Arabic 'rijl al-Jauza' meaning 'foot of the Central One' (Orion was known to ancient Arabic astronomers as the Central One). Although designated beta, at mag. +0.1 Rigel is brighter than Betelgeuse. One possible explanation is that Betelgeuse is variable and may have been close to peak brightness when the labelling was decided.

The seventh brightest star in the sky, Rigel lies 863 lightyears from the Sun. It's a massive object estimated to be 79 times larger than the Sun and around 120,000 times as luminous. It is classed as an Alpha Cygni-type variable exhibiting a small magnitude variation between +0.05 and +0.18. At around 10 million years old it is a relatively young star.

Rigel has a mag. +6.7 companion 9 arcseconds away. Although not particularly faint, Rigel's brilliance makes its companion hard to see. Rigel B is located 2,500 AU from Rigel and although it shares the same proper motion, its orbital period is unknown, probably around 20,000 years. The companion is actually a close binary in its own right, its two components in a mutual 400-year orbit separated by 100 AU. A fourth member of the system sits 44 arcseconds from Rigel, shining away at a rather dim 15th magnitude.

A popular associated target for astrophotography is the blue reflection nebula known as the Witch Head Nebula, IC 2118. It gets this name because it looks like the profile of a witch's face. The nebula sits 2.5° northwest of Rigel and is visually extremely faint. Amazingly, although it's physically located 40 lightyears from Rigel, it is Rigel's light that illuminates it.



STEPHEN TONKIN'S

BINOCULAR **TOUR**

Can't see a bicycle in this month's tour? If at first you don't succeed, Phi, Pi, Psi again

☑ Tick the box when you've seen each one

1 THE MEISSA CLUSTER

10x 50 We'll begin with an easy object to locate and identify: the northernmost point of the triangle of bright stars at the top of Orion: Betelgeuse (Alpha (α) Orionis), Meissa (Lambda (λ) Ori), and Bellatrix (Gamma (γ) Ori). You should see at least 10 stars close to hot, blue-white Meissa, from which a trio of fainter stars leads south to another blueish star, Phi^1 (φ^1) Orionis. The same distance east of Phi^1 is Phi^2 (φ^2) Orionis, a cooler yellow star. Between Phi^2 and Meissa are two short chains of 9th magnitude stars: a yellowish one and a white one. ☐ **SEEN IT**

2 COLLINDER 65

10x 50 Use the triangle of bright stars we started with as an arrowhead to point to a misty patch 6.5° north-northwest of Meissa. This is Cr 65, one of 471 star clusters catalogued by the Swedish astronomer Per Collinder. It's about 4° across, so it fits nicely in your binocular field, enabling you to see lots of chains and groups of stars, the brightest of which is orange CE Tau. There's an interesting optical illusion going on here: CE Tau looks as if it might be closer than the rest of the cluster, but it's actually over four times more distant. ☐ **SEEN IT**

3 ORION'S SHIELD

10x 50 The Pi (π) Orionis stars are usually depicted as an animal hide or a shield. They are not usually given much more than a glance before moving on to the famous objects to the south, but this does them a disservice. The group spans nearly 9° of sky, overflowing the field of view of most binoculars, so you will have to scan around to see it all, but it is a colourful starfield, from white Pi^1 (π^1) Orionis, through to the Sun-like Tabit (Pi^2) down to blue Pi^5 and orange Pi^6. ☐ **SEEN IT**

4 THE VASE

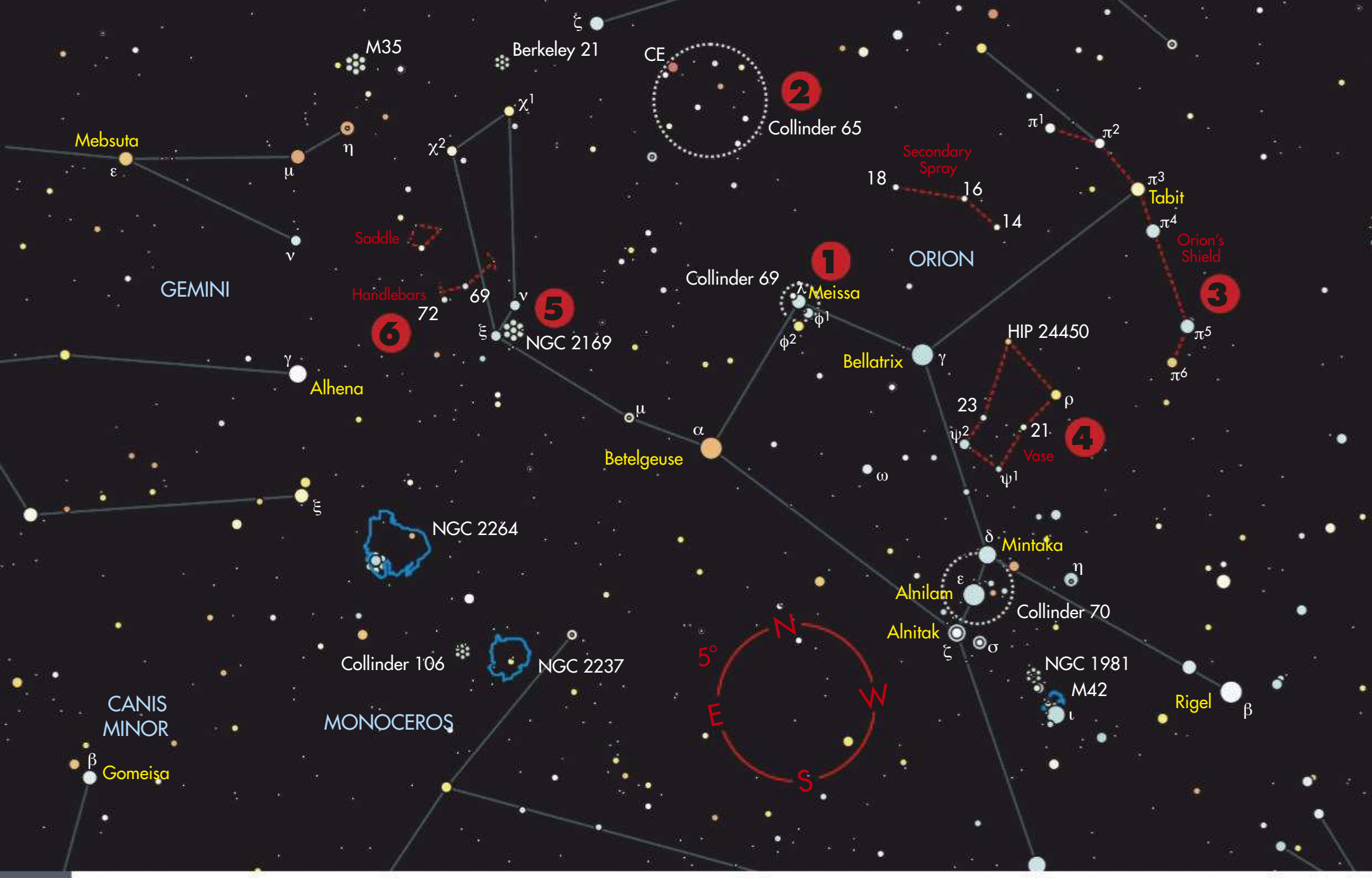
10x 50 If you imagine that the stars of Orion's Shield are a glowing spray of flowers in a vase, the vase itself is another colourful group that will fit into a single field of view. The bottom of the vase, (Psi^1 (ψ^1) and Psi^2 (ψ^2) Orionis) is light blue, but the colour changes to its asymmetrically flared orange rim (Rho (ρ) Orionis and HIP 24450. The background stars add to the illusion: the base of the vase is densest, and the curve from 14 to 18 Orionis creates a smaller secondary spray of flowers. ☐ **SEEN IT**

5 THE 37 CLUSTER

15x 70 Take a line from Alnitak (Zeta (ζ) Orionis) to Betelgeuse, extend it a further 8° northwards to the pair of brilliant white mag. +4.4 stars, Nu (ν) and Xi (ξ) Orionis. Go back 0.5° towards Betelgeuse and you will find a tiny, 7 arcminute-wide rectangular cluster of stars, NGC 2169, with a void in the middle. Mounted 15x70 binoculars will show you that the brighter (8th and 9th magnitude) stars form a two-digit number. In a perfect Universe, Messier would have found this cluster immediately after he'd catalogued M36! ☐ **SEEN IT**

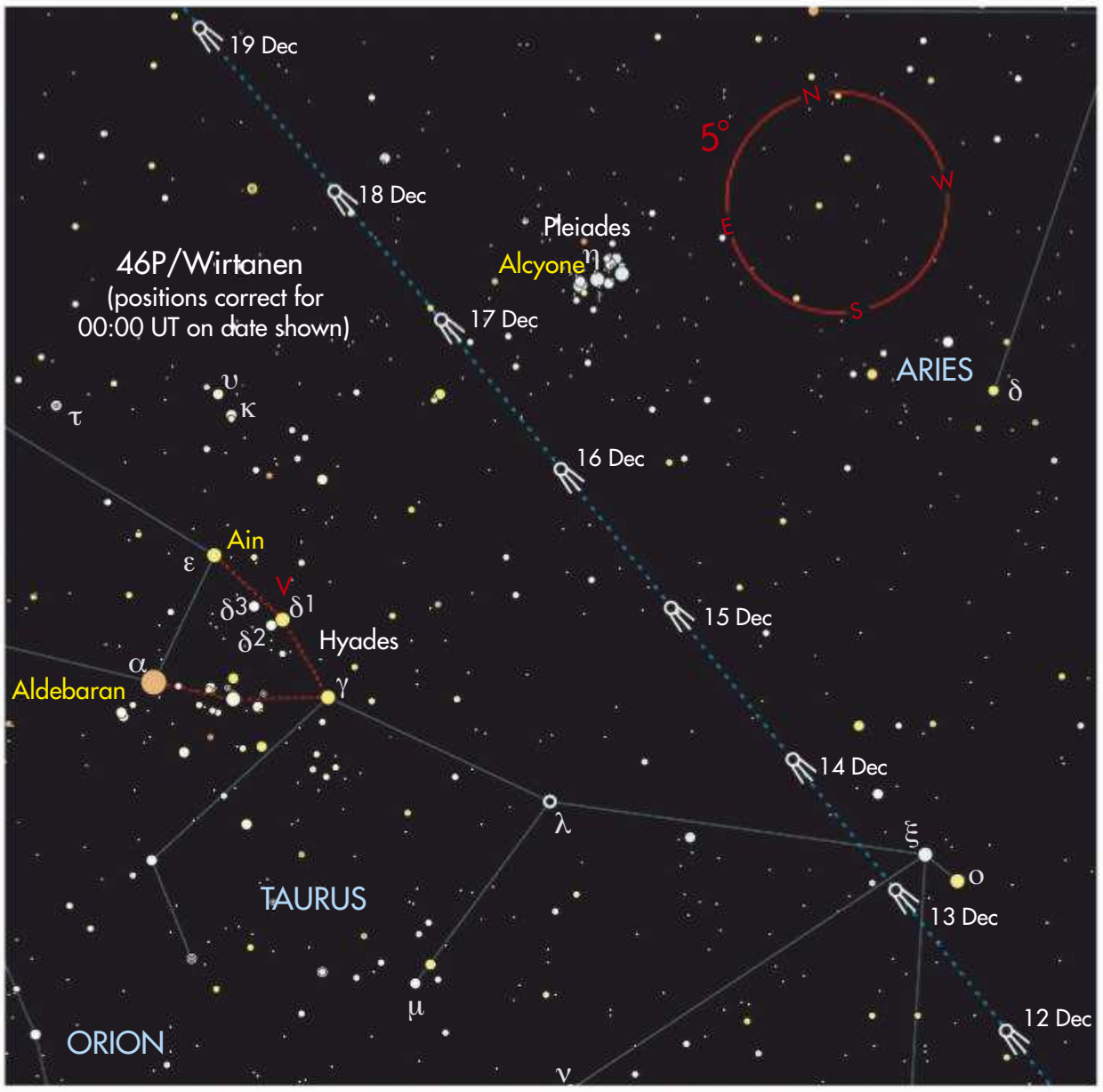
6 THE HANDLE BARS

15x 70 Continue our Alnitak-Betelgeuse line a further 2.5° to the mag. +4.9 69 Orionis. See how it is bracketed by two short lines of 7th and 8th magnitude stars, around 1° to the east and west respectively, like the handlebars of an antique bicycle, with 69 Ori as the front light? We can extend the bicycle image further by including the little kite-shaped asterism 2.5° to the north of 69 Ori as a slightly skewiff saddle. ☐ **SEEN IT**



THE SKY GUIDE **CHALLENGE**

The sky's always on the move, but how much in it can you actually perceive to be moving?



▲ **Comet 46P/Wirtanen's fastest apparent rate of travel will occur mid-month. At this time the comet will be travelling approximately 4.2° a day, or around 11 arcseconds per minute**

Our final challenge for 2018 is, at first glance, an odd one. This month we're challenging you to see something moving in the sky in real time.

There need to be a few conditions to this to make it an actual challenge so we're going to remove obvious 'local' candidates such as meteors, the aurora and artificial satellites. These are just too easy.

With the locals removed, the challenge suddenly becomes a whole lot more difficult… and interesting! When you start to think about it, what is there beyond the confines of Earth that you can actually perceive moving in real time? By moving in real time we mean something that shifts position while you look at it. An example of what we don't mean would be something like the moons of Jupiter where you can see when one has moved, but only after looking away for a while.

One potential candidate is an asteroid that's passing close to our planet. Observed through a pair of binoculars or a telescope, it's certainly possible, albeit rather uncommon, to see an object such as this move perceptibly against the background stars. Another more distant target you might consider is the Sun. If you have H-alpha equipment then rare eruptive prominences can create features that can be seen to move relative to the Sun's limb.

There's another interesting candidate visible in the December sky. Comet 46P/Wirtanen is set to approach Earth to a distance of 0.078 AU or slightly less than 11.7 million km. Ironically this may have a detrimental effect on the comet's apparent brightness, presenting us with a large diffuse object of low surface brightness. However, the comet's nucleus should be visible as an almost star-like point within the comet's diffuse head. In reality the nucleus of a comet is too small to be seen directly and the star-like point you see towards the centre of the head is a gas and dust envelope around the true nucleus. This bright 'spot' is called the pseudo-nucleus.

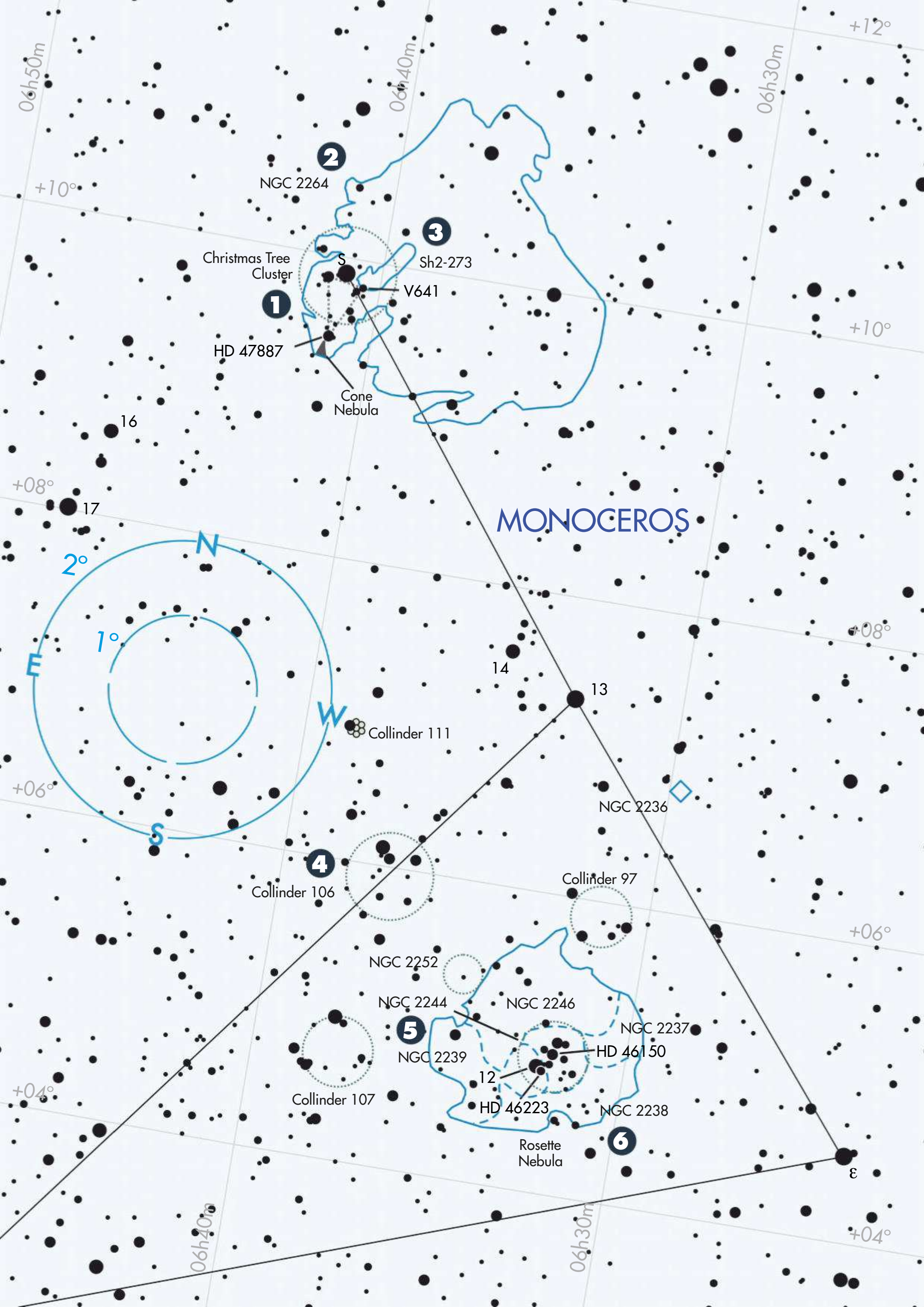
Start with a low-power, wide-field eyepiece and stare hard at the pseudo-nucleus. If you can't perceptibly see it move against the stars, switch to a higher power. You'll need to be careful here because you'll only be able to perceive movement if you can also see stars in the field of view.

The best time to attempt this challenge will be mid-month, when the distance between Wirtanen and Earth is minimised. At its peak rate, Wirtanen will appear to move by approximately 11 arcseconds every minute of clock time. Keep a record of the equipment used, magnification used and date, so that you can identify the exact circumstances when real-time motion was seen – assuming it is seen of course.

"What is there beyond the confines of Earth that you can actually see moving in real time in the sky?"

▲ **With the correct filters and equipment you may see a solar prominence erupt in real time**

PETE LAWRENCE X 3


06h50m
06h40m
06h30m
+12°
+10°
+08°
+06°
+04°
2
NGC 2264
3
Sh2-273
Christmas Tree Cluster
S
V641
1
HD 47887
Cone Nebula
16
17
MONOCEROS
N
E
W
S
2°
1°
14
13
Collinder 111
NGC 2236
4
Collinder 106
Collinder 97
NGC 2252
NGC 2244
NGC 2246
5
NGC 2239
NGC 2237
HD 46150
12
HD 46223
NGC 2238
Collinder 107
Rosette Nebula
6
ε

DEEP-SKY TOUR

This month's star tour starts off with a suitably seasonal theme

☑ Tick the box when you've seen each one

1 NGC 2264 PART 1: THE CHRISTMAS TREE CLUSTER

At mag. +6.5, NGC 457 isn't a tricky object. The official IAU designation NGC 2264 confusingly covers two objects – the Christmas Tree Cluster and the Cone Nebula. For our first target we'll look at the easier-to-see cluster. The key here is to locate the multiple and variable star S Monocerotis, also known as 15 Monocerotis. The star's variability range is small, its brightness barely wavering between mag. +4.6 and mag. +4.7. It marks the trunk of a Christmas tree-shaped cluster of stars. Mag. +7.2 HD 47887, located 26 arcminutes to the south, marks the top of the tree. The upside down tree shape is surprisingly easy to pick out with a small telescope using a low power, wide-field eyepiece. We'd recommend making sure you've identified it correctly before moving on to target two. ☐ **SEEN IT**

2 NGC 2264 PART 2: THE CONE NEBULA

The Cone Nebula also falls under the heading NGC 2264. To find it, start at the Christmas Tree Cluster. Try to spot the reflection nebulosity surrounding S Monocerotis and the small group of stars 8 arcminutes to the southwest. If you can't, chances are you'll not be able to see the Cone. It's a dark nebula formed by an intervening dust cloud blocking light from a brighter nebula beyond. Its shape mirrors the Christmas tree, the cone and the tree being aligned tip-to-tip. The most obvious part of the Cone Nebula is where the background nebulosity is brightest, just south of HD 47887. A UHC filter will really help if you have one. ☐ **SEEN IT**

3 SH2-273: THE FOX FUR NEBULA

The Fox Fur Nebula is often grouped into the confused label NGC 2264 although it is uniquely designated as Sh2-273. Bearing a remarkable resemblance to a fox stole in long exposure photos, its nose is located roughly between S Monocerotis and variable star V641 Monocerotis to the southwest. The fur stole then sweeps in a broad arc around to the northwest for about 0.5°. This is part of a much larger and fainter region of glowing hydrogen gas. A nebula or UHC filter is recommended for viewing the Fox Fur Nebula visually. ☐ **SEEN IT**

4 COLLINDER 106

We take a break from confusion for our next target by heading 3.8° south and 1° west of S Monocerotis. Here you'll find Collinder 106, a mag. +4.6 open cluster. This is a large and sparsely populated object. It has an apparent size measuring 45 arcminutes across and consequently benefits from the use of a low power, wide-field eyepiece. There are around 20-25 stars visible here mostly of 6th or 7th magnitude. Although quite a poor example of an open cluster, it does have the virtue of providing a good comparison with our penultimate target, which can be found 1.7° to the southwest of Collinder 106. ☐ **SEEN IT**

THIS DEEP-SKY TOUR HAS BEEN AUTOMATED

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

5 NGC 2244

NGC 2244 is the open cluster at the heart of the Rosette Nebula. For many, this cluster is the only part of the Rosette they get to see! Its half dozen brightest stars look like a wobbly version of the dots on the six face of a die. The brightest star, 12 Monocerotis in the southeast corner, is a foreground object and doesn't belong to the more distant cluster. The star in the six dots' southwest corner is HD 46223. This is a true cluster member estimated to be 400,000 times brighter than the Sun and 50 times as massive. HD 46150 – the middle-west dot – is even more impressive at 450,000 times brighter than the Sun and 60 times more massive. NCG 2244 is about 18 lightyears across and 5,200 lightyears distant. ☐ **SEEN IT**

6 NGC 2237, 2238, 2239 AND 2246 – THE ROSETTE NEBULA

While our first target had one designation for multiple objects, our last reverses the trend by having multiple designations for one object. The Rosette Nebula is a large, circular patch of nebulosity surrounding the open cluster NCG 2244. It's seen as several nebulous patches designated as NGC 2237, 2238, 2239 and 2246. The nebula is being excited by the hot young stars of NGC 2244. Its 1.3° apparent diameter gives it a low surface brightness, so it's a challenge to see. Observe from a dark sky site with a low-power eyepiece and use a UHC or OIII filter if you have one. A 4-inch scope is enough to see it without filters if the sky's dark enough. Its size is truly stunning; its physical diameter is 130 lightyears across. ☐ **SEEN IT**

◂ **NGC 2264 looks like an upside down Christmas tree, with bright star S Monocerotis at the bottom of its trunk rather than on its top**

YOUR BONUS CONTENT

Print out this chart and take an automated Go-To tour

CHART: PETE LAWRENCE, PHOTO: MICHAEL DEGER/CCDGUIDE.COM

ASTRO**PHOTOGRAPHY**

▲ If you're tracking a comet to keep it in focus, you may run into the problem of stars trailing

Catch a speeding comet

RECOMMENDED EQUIPMENT

DSLR, remote shutter release, wide-field lenses, planetary imaging setup

THE BIG PICTURE

THERE'S MORE THAN ONE WAY TO CAPTURE A COMET LIKE WIRTANEN

Comet 46P/Wirtanen has been lurking in the low southern part of the UK's sky for the past couple of months. It's set to move rapidly northward during December (see pages 52 & 61). As it goes, it'll hopefully fulfil predictions and appear visible to the naked eye. Bright comets aren't common, so it pays to think ahead about ways to image it. This month we take a look at several techniques that can be used reveal different sides to Wirtanen's personality. We also hedge our bets and suggest ways to capture it if, as comets sometimes do, it fails to live up to expectations!

Comet 46P/Wirtanen has been difficult to see from the UK for the past few weeks because of its low southerly declination. That changes in December as the comet streaks north from Eridanus into Cetus, via Taurus, Perseus and Auriga before ending up in Lynx on New Year's Eve.

Wirtanen's December journey will have the comet travelling a total distance of approximately 95° over 31 days taking it past some photogenic deep-sky backdrops – the Hyades and Pleiades open clusters in Taurus mid-month, then NGC 1499, the California Nebula, before heading for a close encounter with Capella (Alpha (α) Aurigae) on 23/24 December.

All but the Capella encounter have a reasonable distance between their deep-sky backdrops, so wide-field set-ups will be necessary to capture these photo opportunities. A typical setup will comprise a DSLR camera fitted with a standard photographic lens. Tracking will extend exposure times but non-driven setups should also be capable of recording the comet and the surrounding objects without trailing, so long as exposures are kept relatively short.

At the time of writing, the jury is out as to how bright Wirtanen will get. A peak above mag. 4.0 could be on the cards and if this does occur it begs the question as to whether it'll be bright enough for less conventional imaging techniques. One interesting opportunity would be the possibility of recording the central coma region, which lies close to the nucleus, using a planetary imaging camera. With a large image scale and lucky imaging techniques, it may be possible to reveal details in the coma not obvious in wide-angle shots, such as dust jets.

The apparent speed of the comet relative to the stars beyond will present additional imaging opportunities. For example, with a tracking setup it will be possible to take sequential images of the comet and add them together in a short movie sequence. This may reveal the faint detail associated with the comet's head and tail, something that can get lost in still images. If nothing else, a comet moving against the background stars is quite an impressive thing to record and show.

This technique has its own challenges. Equatorially tracked setups may start to record motion blur as the comet moves northeast through the constellations. Auto-guiding on the head of a faint comet can be a tricky thing to pull off but in the case of 46P/Wirtanen, the nucleus region may, fingers-crossed, be bright enough for this to work. This will help to reveal any fainter detail present within 46P/Wirtanen, and potentially provide a very important scientific record of its passage.

However you decide to image it, the passage of a naked eye-bright comet at a decent altitude, soaring across the dark December skies in the UK is something to get excited about.

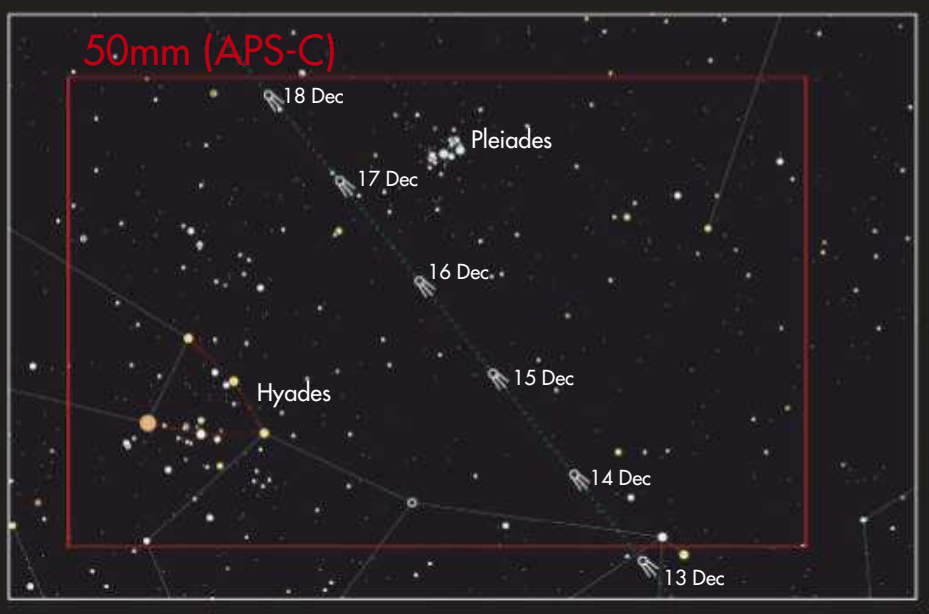
✉ Send your images to: hotshots@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

STEP BY STEP

STEP 1

Wide-field images can be taken with a tracking or non-tracking mount. For non-tracking, you need a medium-high ISO and a wide lens (stop down slightly if edge distortion occurs). Set exposure according to the '500 rule'; divide 500 by the focal length of the lens you're using to get the maximum exposure possible before trailing becomes evident.

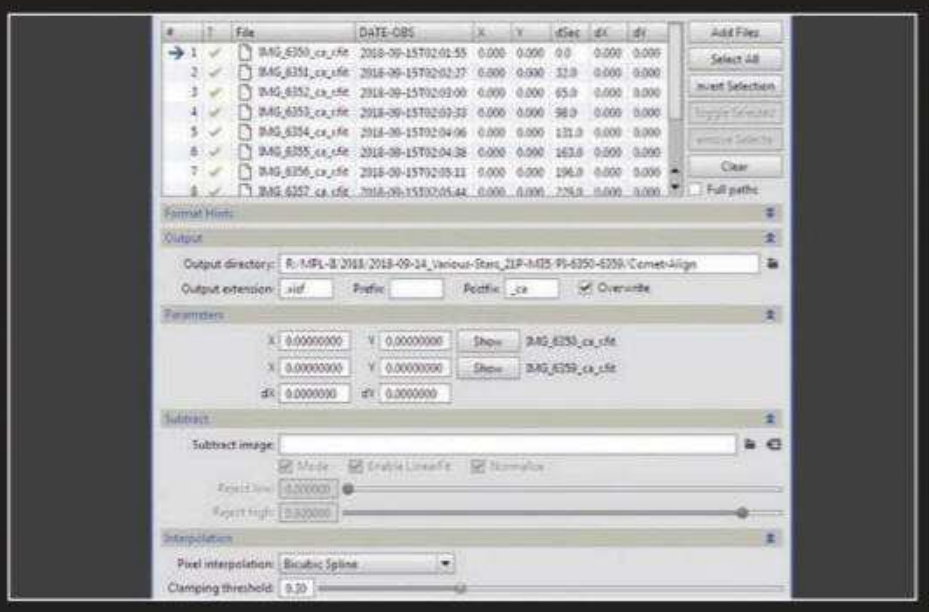


STEP 2

For the comet's Pleiades and Hyades encounter a lens shorter than 50mm will comfortably fit all three in shot. For just the Pleiades and comet, 120mm or shorter is ideal. For the close pass of the California Nebula, try 60mm or shorter. The pass of Capella is close enough for a telescope with a focal length less than 1,000mm to be used.

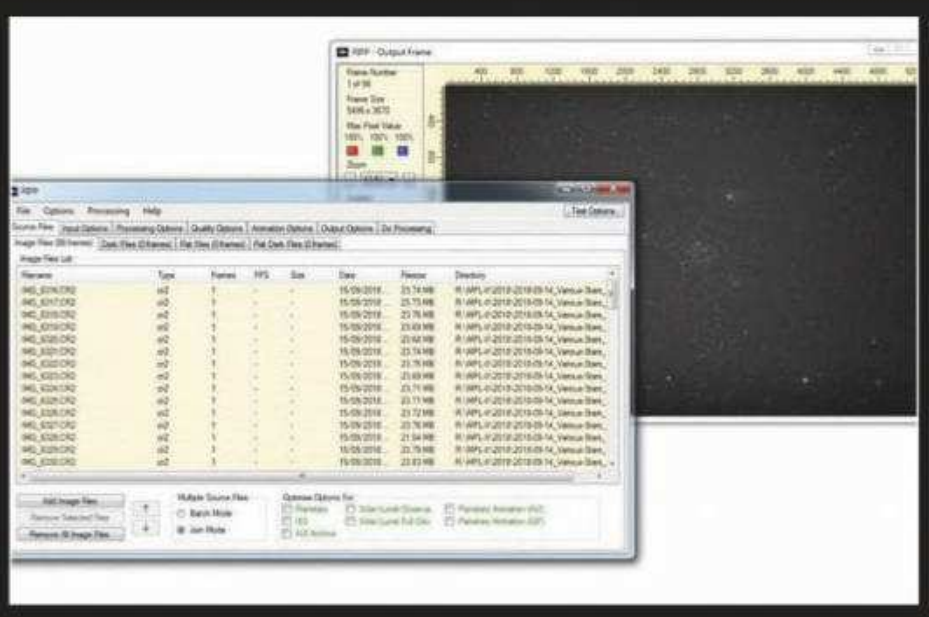
STEP 3

Close-ups on the head of the comet will show any structure present. A DSLR attached to a telescope is ideal. For equatorially driven telescopes, a time limit will apply before the relative motion of the comet blurs the image. Set your camera to a medium-high ISO and try a 30″ exposure. Call up the result and examine it on the camera's review screen.



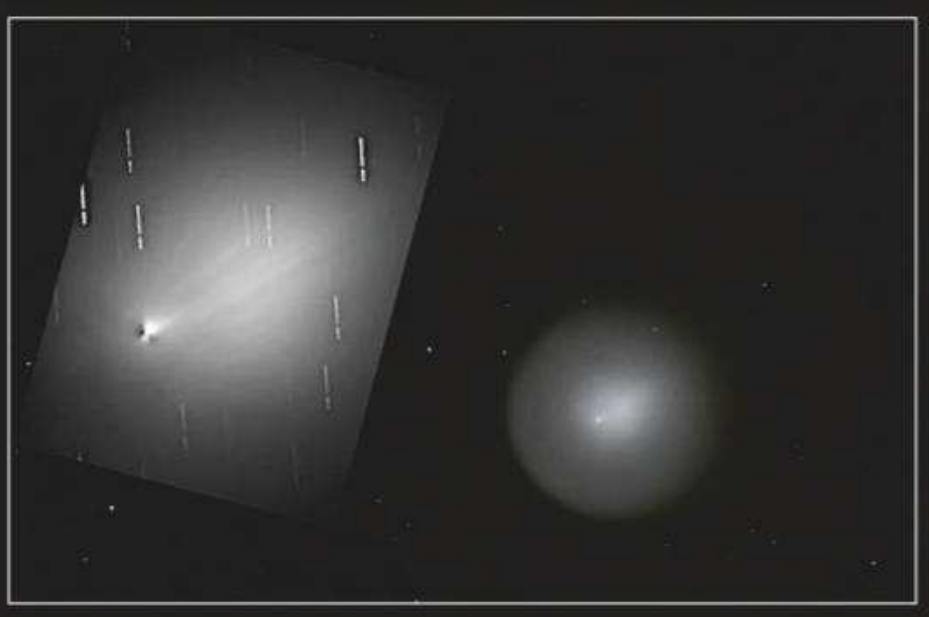
STEP 4

If there's no motion blur on the comet, repeat Step 3 adding 10″ each time. Once you have an optimal exposure setting, take numerous sequential images. Stack these using the comet as a reference (stars will trail). Software such as DeepSkyStacker and PixInsight have routines to assist in combining stacked stars with a stacked comet.



STEP 5

If you collect many images of the comet over an extended period, software such as PIPP (sites.google.com/site/astropipp) can be used to combine them into an animated sequence. The resulting movie will reveal how fast the comet appears to be moving against the background stars. Any faint detail in its head or tail will also stand out well.



STEP 6

If the comet is relatively bright, it may be possible to use a planetary imaging setup to take sequential images of its core region using a high-frame-rate planetary camera. Captured images can be stacked in software such as AutoStakkert! (www.autostakkert.com). This techniques is good for revealing faint dust jets close to the comet's pseudo-nucleus.

ASTRONOMER'S GIFT GUIDE

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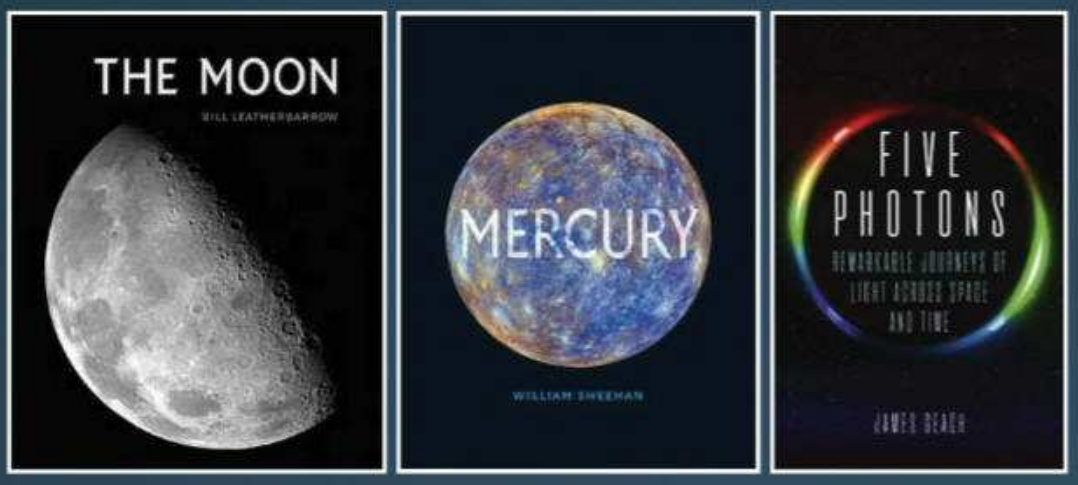

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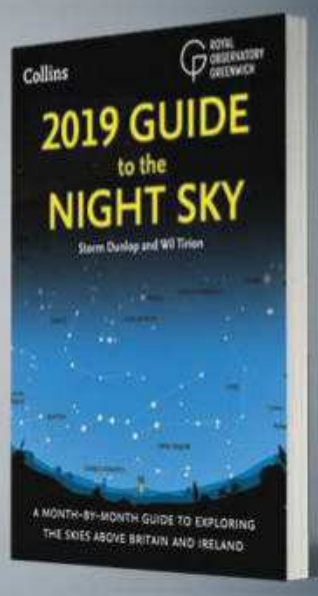

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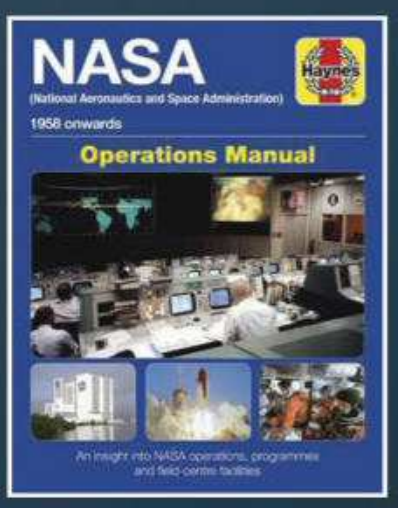
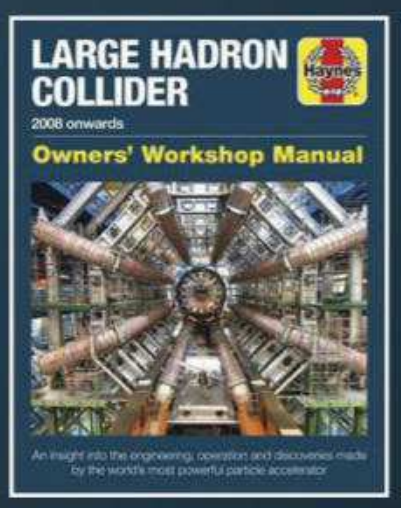
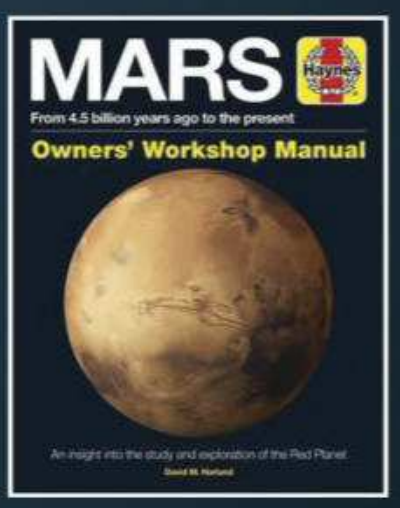
Dark Skies Jewellery

Dark Skies Jewellery

To celebrate the Gold Tier Dark Sky status, which has been awarded to 1500 km² of rural Northumberland by the International Dark Sky Association, the artist has used stunning images of planets, nebulas and galaxies to create a range of jewellery that includes earrings, pendants, bangles, cufflinks and keyrings. Each piece comes with a quality photo card with information on the reverse. This elegant collection of jewellery has been greeted with delight by the star gazing community and would make ideal gifts for Christmas. To see the entire range and buy online please visit **www.darkskiesjewellery.co.uk** or telephone **01830 540346**.







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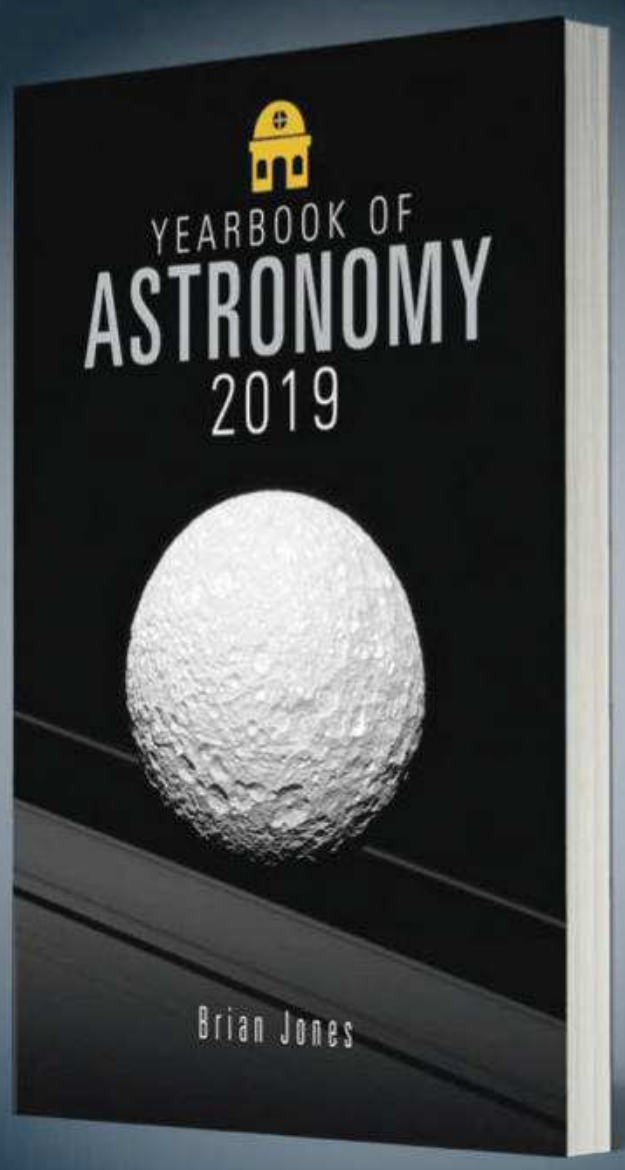

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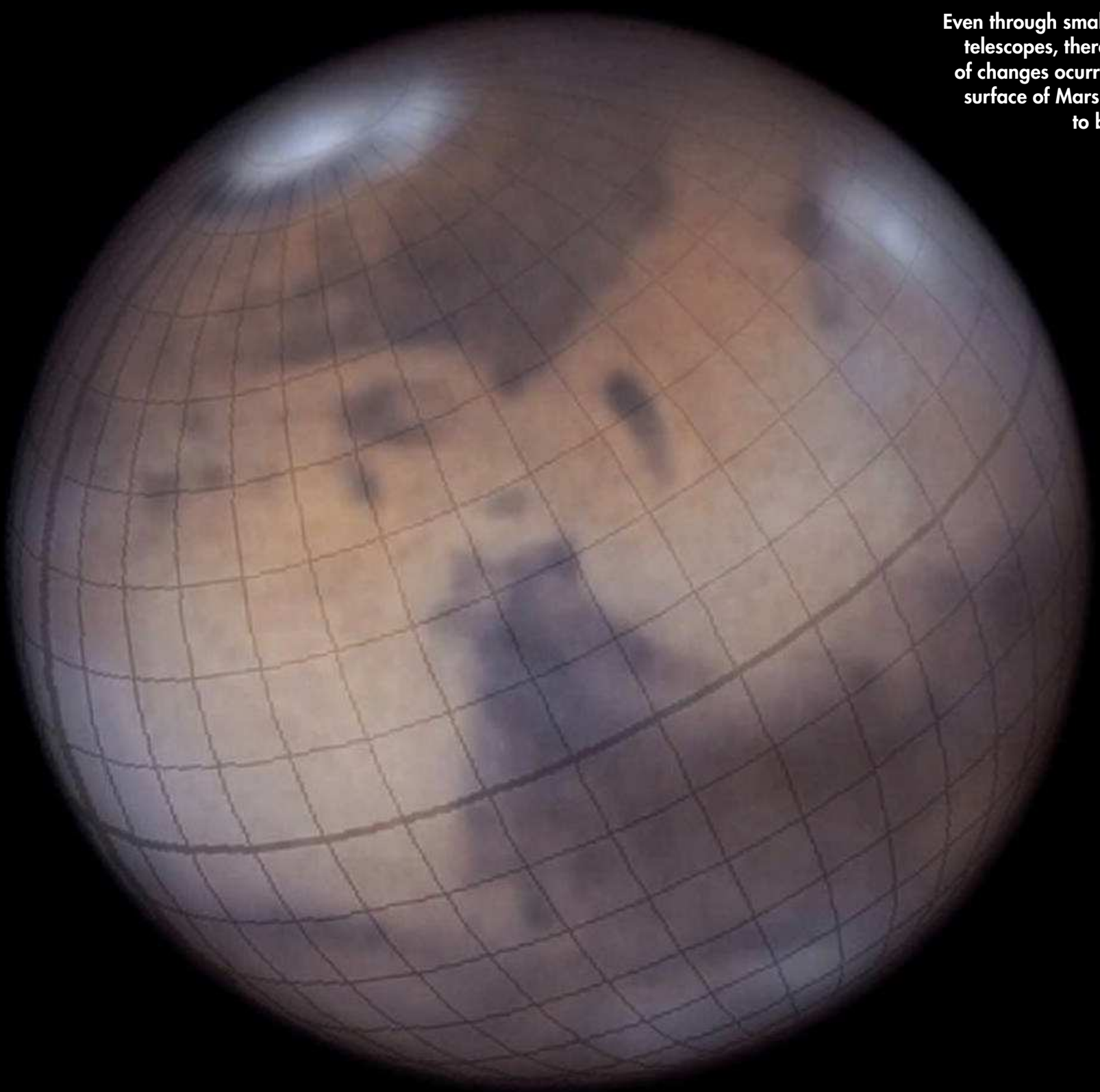


Even through small amateur telescopes, there are a lot of changes ocurring on the surface of Mars that need to be tracked

IMAGING FOR SCIENCE

Part 8: Mars

In this month's instalment of our guide to giving your astrophotos scientific value, we turn to the Red Planet. Find out how to create full-colour images and capture clouds, rocky features and polar caps

PETE LAWRENCE

▲ A full-colour Mars and the filtered images from which it was built. Each filter reveals a different aspect of the planet

Mars is an enigmatic planet. As a rocky body with a thin atmosphere, it presents subtly changing surface features, weather and seasonal variations through amateur telescopes. The seasonal variations include changes to the shape of the polar caps and dust storms, which can sometimes expand to obscure virtually the entire planet, as happened earlier this year.

Oppositions occur every 2.1 years and it's only in the months surrounding opposition that Mars shows significant disc size. Large apertures with long natural focal lengths can extend the observing period but the position of Mars in the sky is important too. Oppositions close to perihelion tend to occur in a low part of the ecliptic. As far as the UK is concerned, this is problematic because of Mars's low altitude. A factor in the planet's favour is its reddish colour. Longer (red) wavelengths tend to be more resilient to seeing issues and this can help give a decent view of Mars, even when it's at low altitude.

ABOUT THE WRITER

Sky at Night **presenter Pete Lawrence is an astrophotographer with a particular interest in digital imaging**

Hardware & software

HARDWARE

- **High-frame-rate camera**
- **RGB imaging filters for use with mono camera**
- **Speciality filters, eg, IR-pass**
- **Filter wheel**
- **Atmospheric dispersion corrector (ADC)**
- **Large-aperture, long-focal-length telescope on a driven mount**
- **A laptop**

SOFTWARE

- **WinJUPOS (freeware, www.grischa-hahn.homepage.t-online.de)**
- **Capture software, eg, FireCapture (freeware, www.firecapture.de) or SharpCap (freeware and commercial, www.sharpcap.co.uk)**
- **RegiStax (freeware, www.astronomie.be/registax)**
- **AutoStakkert! (freeware, www.autostakkert.com)**
- **Image editor, eg, GIMP (freeware, www.gimp.org) or Photoshop (commercial, www.adobe.com/uk/products/photoshop.html)**

PETE LAWRENCE X 4

Submit your pictures for science

"The BAA Mars Section has systematically studied Mars since 1892. We welcome observations of all sorts, from simple sketches to processed electronic images, but in order to ensure that these records are of the greatest value to us, certain criteria need to be met.

First, it is important that all observations are properly timed, using Universal Time (UT). British Summer Time is to be avoided! It is normally obvious which way up the image is (and the Mars Section likes south at the top, as in the usual telescopic view), but if a zenith prism has been used (which inverts east and west), that should be stated. We also need to know from where the observation was made, the aperture and type of telescope, the type of camera (if used) and details of any filters. Was the image processed or enhanced? It is also worthwhile adding a short description, written beneath the image or drawing. For example, a new dust storm might have been detected, or a related change in an albedo feature.

Observations can only ever be of any scientific use if they are sent to an organisation like the BAA. Moreover, they are of the greatest value only if they are contributed promptly. Waiting till the end of an apparition is not a good idea: you may miss the chance of making a great discovery!"

Dr Richard McKim, British Astronomical Association

PROJECT 1

Imaging BASICS

A low gain and a high frame rate will help you get 'lucky' when imaging Mars

Mars is best imaged using a high-frame-rate camera. Around opposition its magnitude is sufficient to allow imaging at low gain and high frame rates, optimal settings for the technique of 'lucky imaging'.

Under typical seeing conditions, the recommended imaging resolution is 0.25 arcseconds per pixel. This can be extended to, say, 0.1 arcseconds per pixel under exceptional seeing. The optimal focal length for this can be derived using the formula:

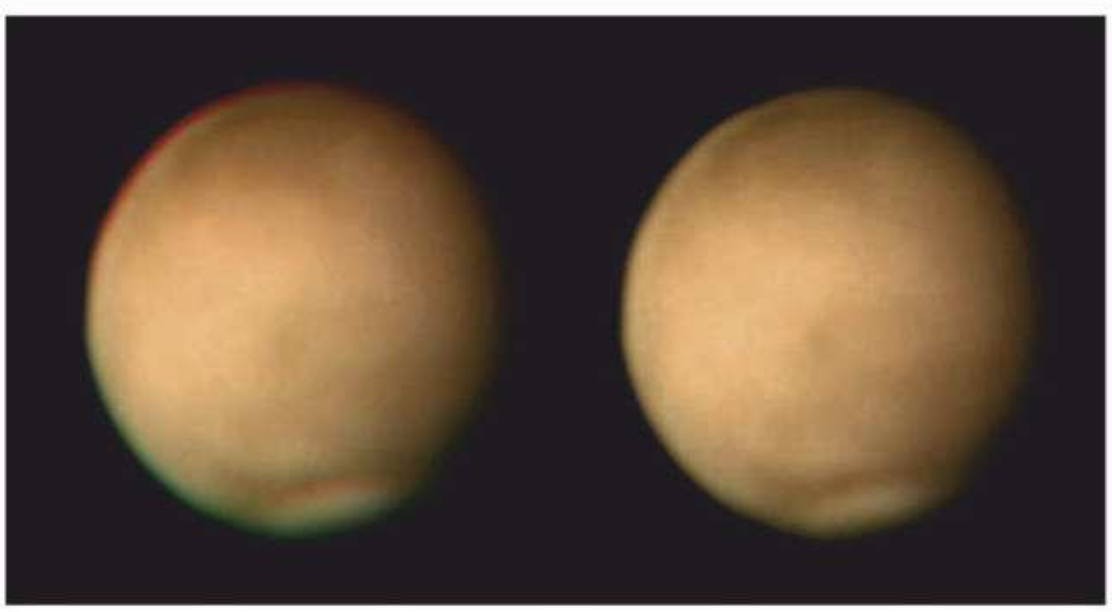
Focal length = 206.3 x pixel size (microns) ÷ [desired arcsecond per pixel value]

We can simplify that formula to: focal length for 0.25-inch per pixel = 825.2 x pixel size (microns) and focal length for 0.1-inch per pixel = 2,063 x pixel size (microns). As an example, for a 5.6 micron sensor, 0.25-inch per pixel resolution is achieved at 4,621mm and 0.1-inch per pixel at 11,553mm. In practical terms these values are guides and the use of optical amplifiers such as Barlows or Powermates to get close to them is sufficient.

Mars rotates every 24h 37m. This means that a feature measuring 0.25 arcseconds at a favourable opposition will move its own width in around four minutes. For this reason, capture sequences should be completed in under this time to avoid motion blur. For 0.1 arcseconds resolution the time limit is slightly under two minutes. Monochrome cameras exacerbate this situation if you want full-colour images. The cumulative time to take red, green and blue images, plus time to change filters and re-focus, needs to be under the resolution time limit. Imaging Mars with a one-shot colour camera largely removes the constraint. A brighter image – all three channels being delivered at once – allows for faster frame rates and reduced overall capture times.

The difference in the apparent size of Mars when it's at its most favourable opposition and when at its most distant from Earth

▲ A full-colour image of Mars can be created using a monochrome camera and Red, Green and Blue filters, but it pays to keep an eye on the overall capture time



▲ An atmospheric dispersion corrector (ADC) reduces atmospheric colour fringing

Low altitude appearances of Mars or any planet will be subject to atmospheric dispersion. This is an atmospheric effect that spreads the light of an object into a spectrum causing colour fringing. The effect gets worse with diminishing altitude. The use of an atmospheric dispersion corrector is advised to correct this issue. ►

PROJECT 2

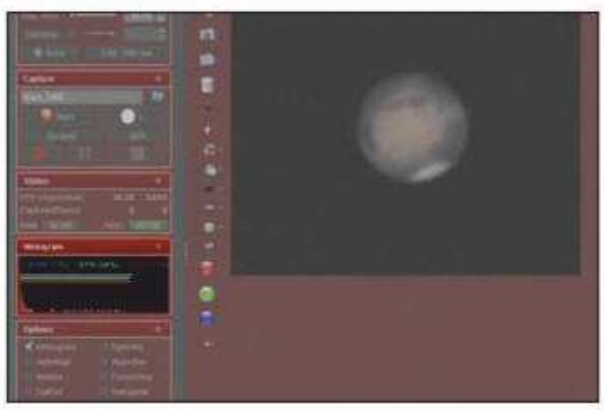
Using FILTERS

Imaging Mars in blue or infrared can reveal different aspects of the planet

You can image Mars through filters to isolate specific aspects of its appearance. What kind of camera you're using will dictate which filters work best. For example, a monochrome camera with an RGB imaging filter can be used to create full-colour images. Blue-filtered images are useful for showing clouds in the thin Martian atmosphere. Infrared pass filters also work well with Mars, producing crisp definition between the dark, exposed rock features, lighter deserts and polar caps. Depending on the sensor response curve, either monochrome or colour cameras may be suitable for use with infrared pass filters.

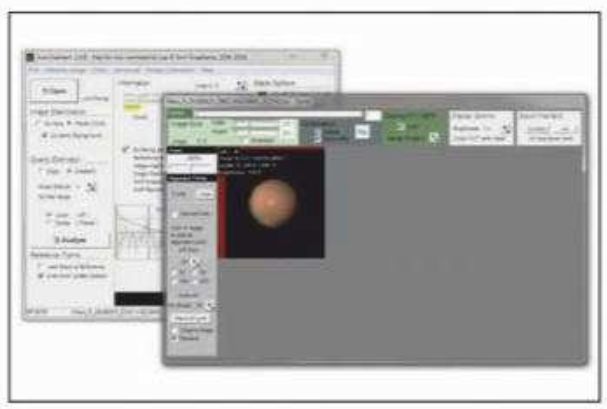
Step 1

Owing to the time constraints necessary to create a full RGB capture sequence using a monochrome camera, a filter wheel is recommended. Manual or automated versions are available. A re-focus is required after each filter change.



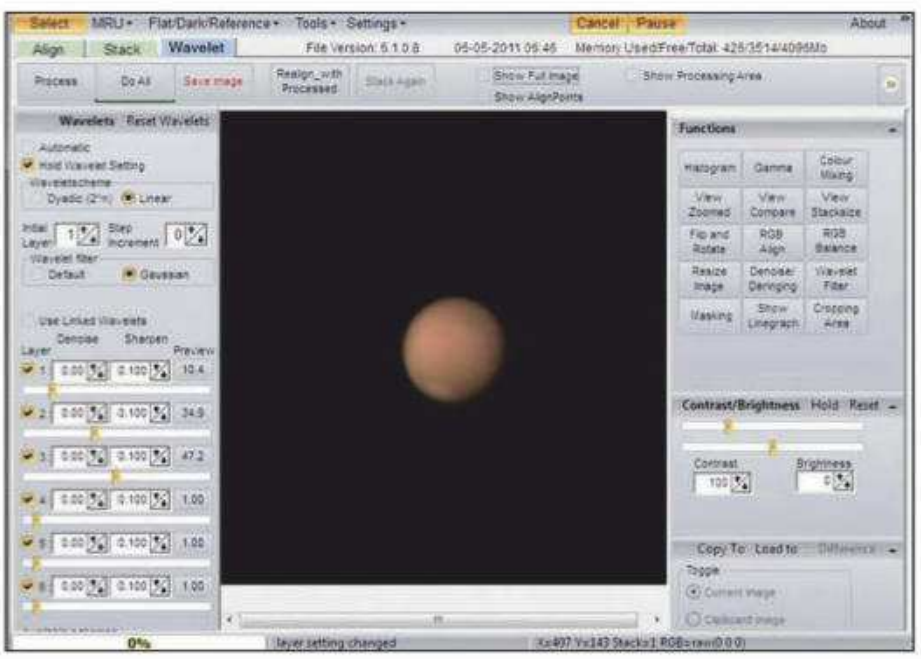
Step 2

A typical full capture sequence should be completed in less than four minutes. Blue typically takes longer because it appears dimmer. Using your capture software's level indicator, aim to capture at similar peak levels of around 70-80 per cent.



Step 3

Use a registration-stacking application such as AutoStakkert! to process each capture file. The number of stacked frames depends on the sky quality but typically, for a total capture count of 3,000 frames, 10-30 per cent works well.

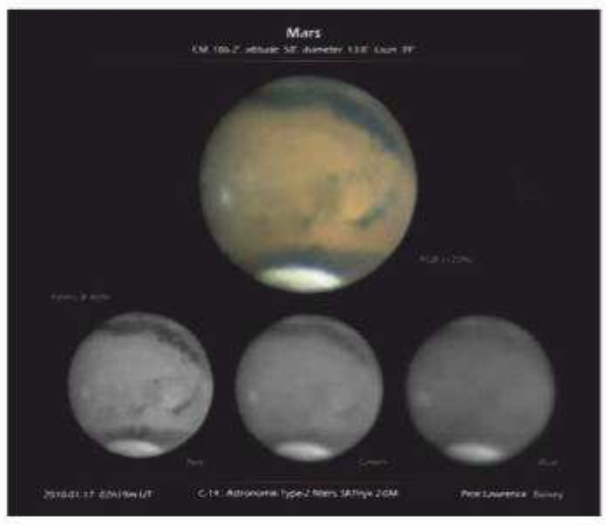


Step 4

Individually processed frames can be wavelet-sharpened using RegiStax. Once done, an image editor such as GIMP or Photoshop can be used to assemble the individual colour channel results into a full RGB image.

Step 5

IR-pass captures can be processed in the same manner. Using an IR-pass image to increase luminance contrast in an RGB result should be stated on the image, as it may produce a false impression of relative feature intensity.



Step 6

The final image should be presented according to the requirements of the organisation to which you intend to send it. Date, time, observer, instrument detail, location, filters used and image orientation should be shown on the image.

ALL PICTURES: PETE LAWRENCE

PROJECT 3

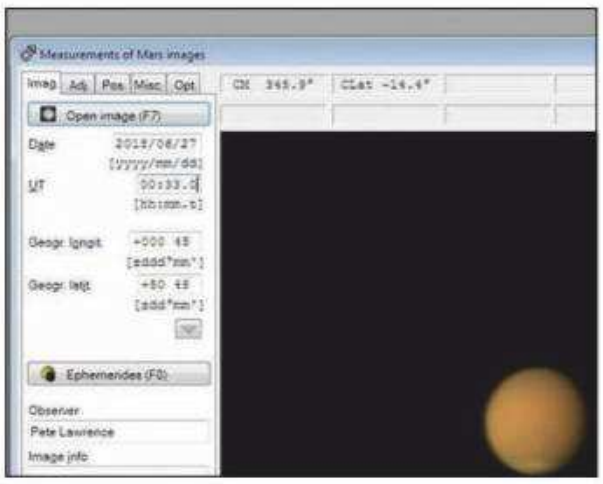
Measuring features with WINJUPOS

How to create a map of Mars so that you can keep track of how its features are changing

Despite its name, WinJUPOS supports all the main planets, the Sun and the Moon. It's useful for preparing imaging sessions, providing simulated views of features at specific dates and times. In addition, it has an excellent image measurement system that can be used to pre-prepare images for analysis or subsequent image processing routines such as de-rotation, which effectively allows you to 'undo' a planet's rotation to avoid motion blur. WinJUPOS can also be used to create maps of Mars during an apparition which you can compare with previous apparitions to see how its surface features are changing.

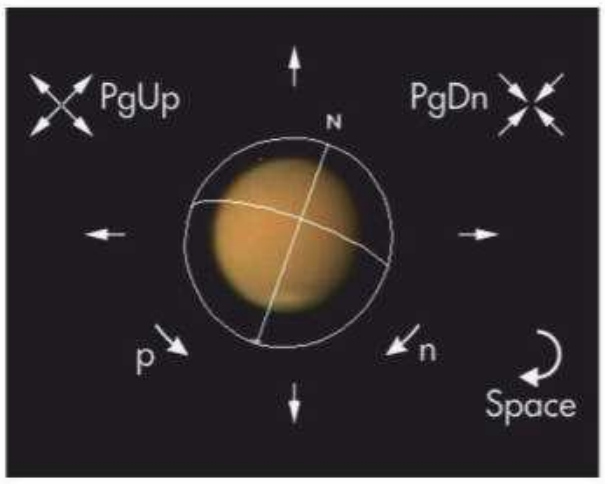
Step 1

Open WinJUPOS and from the Program menu option click on Celestial Body and select Mars. From the Recording menu option select Image Measurement. In the window that appears, from the Imag. tab, click Open image (F7).



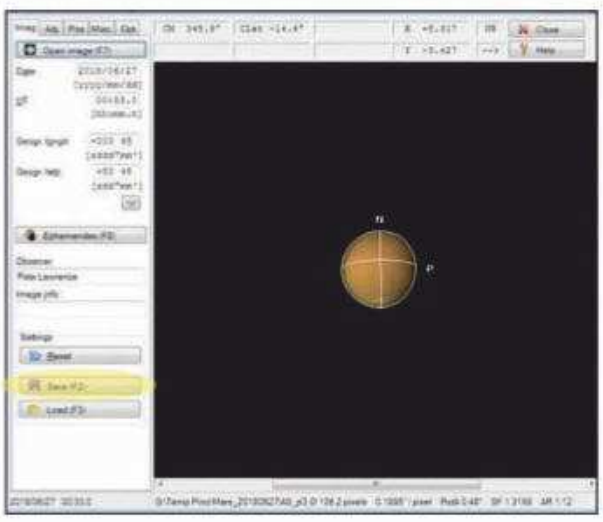
Step 2

Enter image values under the Imag. tab as requested. Select the Adj. tab and ensure the Draw Outline Frame box is ticked. Press F11 (or Outline Frame Automatic detection) to align frame to image.



Step 3

Adjust the outline frame to match Mars's limb and orientation: arrow keys move the outline; N rotates clockwise; P rotates counter-clockwise; PgUp enlarges; PgDn shrinks; space bar rotates by 180°. Use LD compensation to brighten the planet's limb if required.

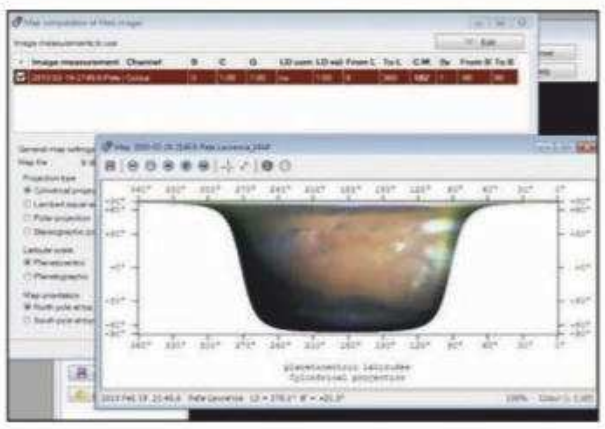


Step 4

Save as an .IMS (image settings) file via the Imag. tab's Save button. Repeat for all capture images. It is recommended that once the outline frame has been set, leave it unadjusted for all similar images from the same session.

Step 5

To create a map from several .IMS files, select Analysis Map Computation… Click the Edit button and add the .IMS files to be used. Define where the output file should go in the Map file input box.



Step 6

Select the projection type required – the process is quick enough for experimentation – and press the Compile Map button (F12). WinJUPOS will automatically join .IMS files taken at different dates to provide a more complete picture.

Dark sky SPAIN

Clear skies, great views of the southerly constellations and some well-organised astro tourism all make Spain a go-to dark sky destination, writes **Jamie Carter**

Perseid meteors streaking above the Albanyà Astronomical Observatory in Catalonia

When it comes to stargazing and astronomy, there are few more tempting locations in Europe than Spain, where astro tourism is taking off in a big way.

Although a big part of Spain's attractiveness to amateur astronomers is the better chance of clear skies than in northern Europe, there's another reason to do astronomy here that doesn't get talked about as much as it should, and that's latitude. Up near the border with France, locations like Albanyà and Parc Astronòmic Montsec are at around 41°N, while Malaga in the south lies below 37°N. That puts the equatorial constellations much higher in the sky than in northern Europe year round, notably Sagittarius in the summer. Not only does Sagittarius contain the Galactic core, but it's also home to some fabulous deep-sky objects including the Lagoon Nebula (M8), Omega Nebula (M17) and the Trifid Nebula (M20), to name but a few.

Most of the places featured here are in protected areas that boast natural darkness, some of them certified as Starlight Reserves, Starlight Tourism Destinations and Starlight Hotels by the Starlight Foundation (fundacionstarlight.org).

With clearer views of some of the night sky's most beautiful objects, plenty of rural areas free from light pollution and an ever-increasing, well-organised network of Starlight Reserves and stargazing-friendly accommodation, Spain is worth an entry on every stargazer's bucket list.

Sierra Sur de Jaén Starlight Reserve, Andalucía

One of the scopes used on the night sky tours organised by AstroAndalus

If you're in Andalucía to see the Alhambra in Granada or the Mezquita in Cordoba, consider driving for an hour to the fringes of the Sierra Sur de Jaén Starlight Reserve. A sparsely-populated rural area, it boasts over 300 clear nights a year and is home to the Observatorio Andaluz de Astronomía at La Pedriza, which runs occasional night-sky observation events and workshops. For a more organised astro tourism experience, head to Casa Olea Starlight Hotel. This six-room boutique B&B on the fringes of Sierra Sur de Jaén has night-sky-friendly lighting and holds regular stargazing weekends, the next one being a three-hour, New Year's Eve stargazing and tapas event, hosted by local astro tourism company AstroAndalus (www.astroandalus.com).

More info: www.casaolea.com ▸


At e-EyE you can rent space in a state-of-the-art observatory shed

e-EyE, Extremadura

About 140km north-west of Seville in Extremadura near the Portuguese border is e-EyE, a comprehensive astro tourism complex ideal for amateur astronomers after clear-sky observations.

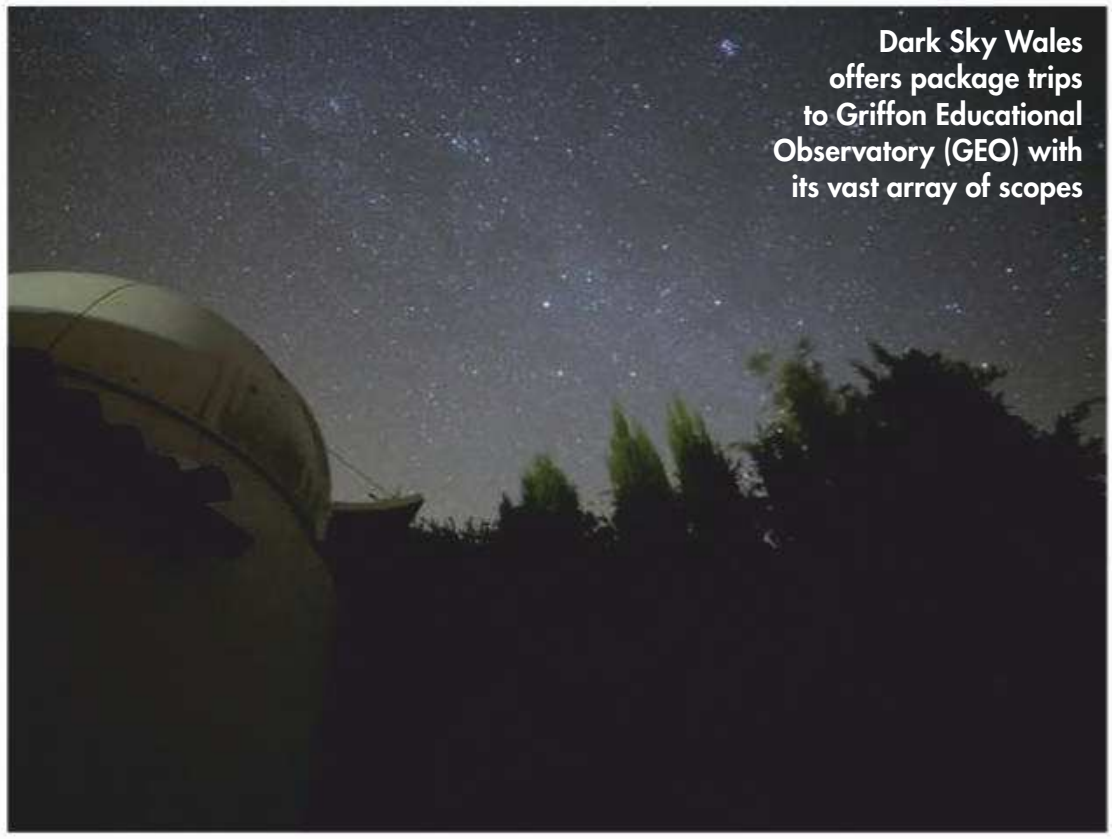
e-EyE stands for Entre Encinas y Estrellas, which translates as 'between oaks and stars'. Certified a Starlight Reserve in 2016 and with a typical sky quality meter reading of 21.5 to 22, e-EyE has 250 clear nights a year, which visitors can enjoy by renting a section in a state-of-the-art observatory shed. Each section has an independent roof, fibre optic internet access and Wi-Fi, and there's a team of technicians on hand. You can even leave your own telescope here and control it remotely from anywhere in the world. Events are held around meteor showers and the complex also organises star parties.

More info: www.entreencinasyestrellas.es

Griffon Educational Observatory, El Bosque, Andalucía

Fancy a few nights' guided group observation and astrophotography tuition in rural Spain? Twice a year Dark Sky Wales organises a residential trip based in El Bosque, including three nights' access to a veritable toy box of telescopes. Allan Trow and Martin Griffiths from Dark Sky Wales host along with Andy Burns from Wiltshire Astronomical Society. The star attraction is a domed 6-inch iStar refractor, though there's also the chance to use Dobsonians, Tele Vue refractors, astrographs and Sky-Watcher EQ6 and EQ8 mounts. The trip includes wide-field imaging in the surrounding Sierra de Grazalema Natural Park, notably from the Puerto del Boyar mountain pass.

More info: darkskywalestrainingservices.co.uk


Dark Sky Wales offers package trips to Griffon Educational Observatory (GEO) with its vast array of scopes


The Monastery of Santo Toribio de Liebana in Cantabria in northwest Spain, which has an Atlantic weather system that's not kind to stargazers

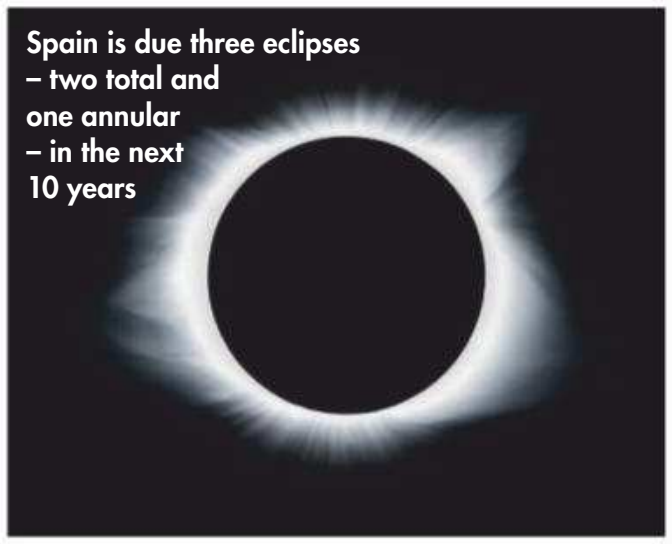
Searching for Spanish clear skies

While the Iberian peninsula has much to offer stargazers, some areas are more suited than others

Although the southerly latitudes and clear skies of much of Spain make it an attractive location for amateur astronomers, don't assume that the entire country is ripe for stargazing – it definitely is not. From a weather perspective it's best to avoid northwest Spain. The regions of Galicia, Cantabria and the Basque Country in the north of the country are subject to an Atlantic weather system that is not kind to stargazers.

In the northeast, the Pyrenees mountains that divide France and Spain act as a natural barrier against clouds and light pollution from cities. The rest of Spain has a Mediterranean climate and enjoys many nights of clear skies throughout the year. Summers and winters are dry, with most of the rain falling during autumn and spring.

▼ **Star trails above the Albanyà Astronomical Observatory**



Spain is due three eclipses – two total and one annular – in the next 10 years

Iberian eclipses

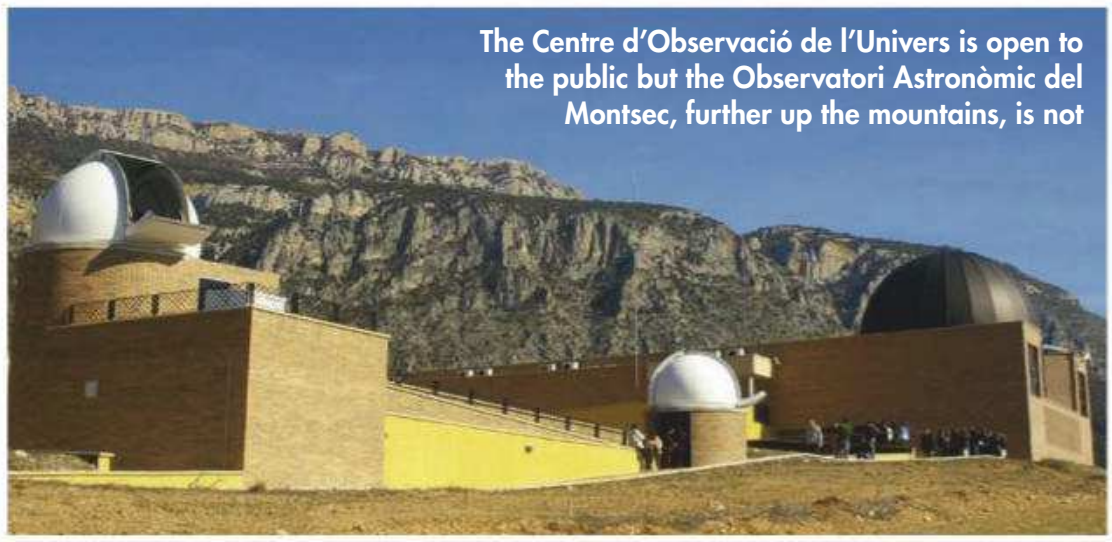
Although a few years away yet, it's worth knowing that on 12 August 2026, Spain will experience the first total solar eclipse in Europe since 1999. Less than a year later, it will witness another total solar eclipse on 2 August 2027, and remarkably, an annular solar eclipse on 26 January 2028.

Albanyà, Catalonia

Here's a great location for a summer astro camp. About 85km north of Girona in Catalonia (and not 30 minutes from the beaches of Costa Brava) in the north-east corner of Spain near the French border is the rural village of Albanyà with the Albanyà Astronomical Observatory nearby. It became the first International Dark Sky Park in Spain in 2017, though a campsite adjacent to the observatory, Bassegoda Park (which also has bungalow accommodation), is itself a Starlight Reserve. The observatory welcomes visitors and holds regular stargazing sessions, while its resident astrophotographer Juan Carlos Casado hosts frequent tutorials. However, its astronomers also collaborate on serious research into asteroids and exoplanets. The observatory is closed in January and most of February.
More info: www.observatorialbanya.com

Parc Astronòmic Montsec, Lleida, Catalonia

Much further inland than Albanyà, but also in Catalonia, is this certified Starlight Reserve and Starlight Tourism Destination in the Montsec mountains. Sheltered from coastal cloud and from the snows of the high Pyrenees, clear skies are common above Parc Astronòmic's two facilities. The Observatori Astronòmic del Montsec, on a mountaintop, is managed by the Catalan Space Institute and focused on research (so not open to the public), while the Centre d'Observació de l'Univers (COU) is in the valley and hosts an exhibition and planetarium show, and also conducts guided tours of its Parc de Telescopis. There's no accommodation here; visitors are asked to stay in the villages of the surrounding Montsec mountain range.
More info: www.parcastronomic.cat ▸



The Centre d'Observació de l'Univers is open to the public but the Observatori Astronòmic del Montsec, further up the mountains, is not

Teleférico Benalmádena, Málaga, Andalucía

The peak of Mount Calamorro, accessed by cable car, is a popular spot for setting up telescopes

Just as Albanyà is an easy astro excursion during a family holiday on the Costa Brava, Mount Calamorro is a must-visit destination for stargazers if you happen to be staying on the Costa del Sol, and the Teleférico Benalmádena cable car offers a fantastic way of getting there. Amateur astronomers from the Málaga Society of Astronomy set up telescopes on the peak of Mount Calamorro, just south of Torremolinos, from 10pm every night each year during July and August. The view from on high overlooks the Mediterranean. Special events are also held, most notably for the Perseid meteor shower, which in 2019 peaks on the night of 12 August and the early morning of 13 August.
More info: www.telefericobenalmadena.com

ABOUT THE WRITER
Jamie Carter is a seasoned astronomer and author of *A Stargazing Program for Beginners: A Pocket Field Guide*

Spain's stargazing sites

Plan your stargazing trip to Spain around some of the country's top astronomy hotspots

1 Sierra Sur de Jaén Starlight Reserve, Andalucía
2 e-EyE, Extremadura
3 Griffon Educational Observatory, El Bosque, Andalucía
4 Albanyà, Catalonia
5 Parc Astronòmic Montsec, Lleida, Catalonia
6 Teleférico Benalmádena, Malaga, Andalucía

PARQUES REUNIDOS GROUP, ISTOCK

Few places can coincide with the beautiful and undiscovered hidden winter fjords of Northern Norway. The rough and mighty Alps are raising from the sea level to the highest peak are powdered with snow and blue winter light. Even in the darkest period of the polar night the blue pastel colours of the sky are magnificent. In addition, the mysterious landscape is often illuminated by the legendary Northern Lights during clear nights. Join the comfortable and exclusive expedition ship M/V Quest, with 26 cabins and an experienced crew. Let´s hunt the northern lights and wildlife, and show you amazing Northern Norway.

ARCTIC EXPEDITION

We sail from 11th of January – 14th April 4- or 5-day trip.
Introduction price: from NOK 4250, - per person per day.
Included: Accommodation, full pension, guiding every day, snowshoe hike and program on the boat.
Coffee/tea/water always available.
Ready to book or want to know more? Info@arcticexpedition.no

SKILLS

Brush up on your astronomy prowess with our team of experts

The Guide

With
Nicholas Joannou

Eyepieces: the basics

Eyepieces may be smaller than telescopes but they're the key to observing

Eyepieces determine a telescope's field of view and its magnification

ISTOCK, ILLUSTRATIONS BY PAUKL WOOTTON, STEVE MARSH X 3

With a telescope and a suitable mount, the single accessory that will do the most to enhance your observing experience – no matter what size of telescope you're using – is a good quality eyepiece. After all, it's the eyepiece and not the telescope that actually produces the magnified image.

A telescope's job is to gather light; as much light as possible in order to make distant, faint objects look brighter. They do this with an objective lens (in a refractor) or an objective mirror (in a reflector) and the aperture of the objective is the key – the wider it is, the more light the scope can gather. The objective then concentrates that light at the focal point inside the scope. You can buy telescopes that make claims for high magnification or zoom functions, but these are gimmicks that, for the most part, you can ignore.

It's the eyepiece that takes the gathered light and turns it into the sharp image that reaches your retina. It's the eyepiece that controls how large (how magnified) that image appears. And it's the eyepiece that determines the field of view (FOV) – how big a swathe of the sky you're able to see. So, what you need is a selection of eyepieces to match each of your different observing objectives.

All eyepiece barrel sizes are standardised to either 1.25-inch or 2-inch. There is no inherent advantage in one over the other; the difference is only to accommodate the physical limitations of lens sizes as they become larger or variations in design, nothing more.

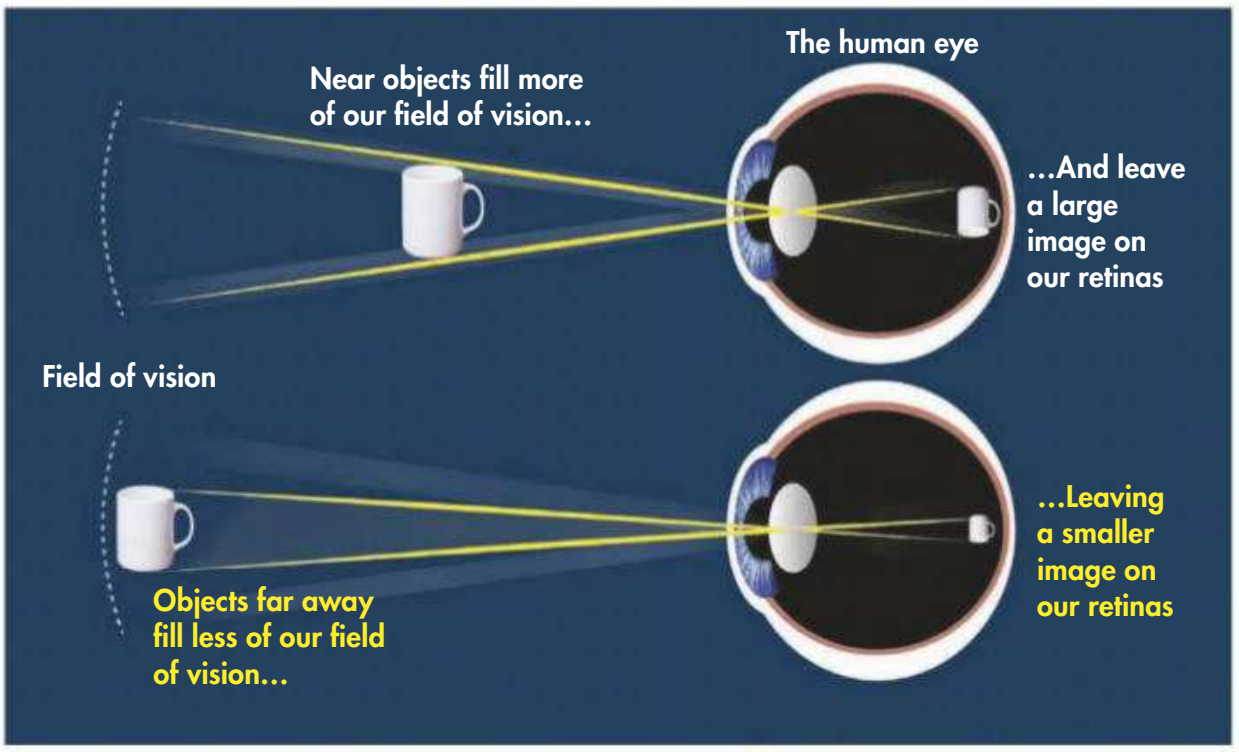
You choose which eyepiece to use according to how you want to 'frame' your chosen target in the field of view (see 'Field of view', below right) at the desired magnification. It's a little counter-intuitive, but you will generally need higher magnifications for objects that are relatively close to Earth, such as the planets, and lower magnifications for larger, more distant objects, such as galaxies. This is because deep-space objects usually take up a larger area in the sky than the points of light formed by the stars and planets. You also need to take into account that the more you magnify an image, the fainter it will appear, so high magnification of distant, faint objects has its own problems.

Choosing what you need

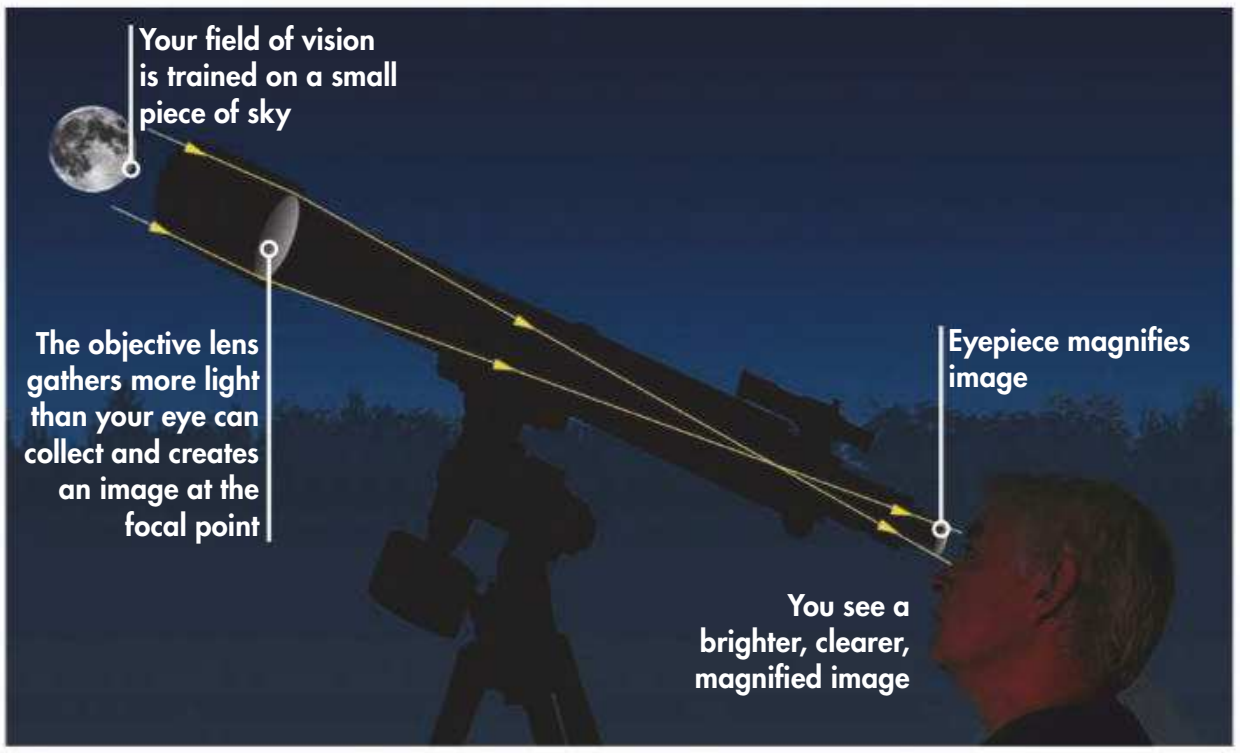
To calculate the magnification an eyepiece will achieve with any given telescope, simply divide the focal length of the telescope (usually written on the scope's body near the focuser or the front lens) by the focal length of the eyepiece (found on its collar).

Another important factor in choosing eyepieces is eye relief, or how far away from the eyepiece's lens your eye needs to be to see the entire the field of view. It's a matter of viewing comfort and for anyone wearing glasses, a long eye relief is preferable.

Of all the different types of eyepieces available, the Plössl eyepiece is perhaps the most common, usually with an FOV of



▲ A basic understanding of how the human eye works helps explain the function of eyepieces



▲ A telescope collects light; it's the eyepiece that magnifies the image that reaches our retinas

40-50° and a short eye relief. It's an effective all-round option that can vary in individual quality and price. Not as common these days, but still in use are orthoscopic eyepieces, which have similar attributes to the equivalent Plössls, but are usually not quite as good – although they are useful for Moon and planet observations. Then there are wide- and ultra-wide-angle eyepieces, that offer very large fields of views up to 110°. These are good for clusters of stars, deep space objects and close-up details on the Moon.

► A Barlow lens can be used to double or triple an eyepiece's magnification

A worthy addition to any eyepiece collection is a Barlow lens, which is not so much an eyepiece, as an eyepiece's friend. A Barlow lens intercepts the light from the telescope before giving it to an eyepiece, doubling or tripling the magnification you would get from an eyepiece alone. A single well-made Barlow effectively doubles the number of eyepieces you have.

A good general collection of eyepieces for beginners would include a high magnification eyepiece; a wide/ultra-wide angle eyepiece; a medium power, general purpose eyepiece; and/or a Barlow lens. This will give you a good selection of magnifications and FOVs, ready for use on many different objects.

NICHOLAS JOANNOU is an elected fellow of the Royal Astronomical Society

Field of view

Field of view (FOV) is how much of the sky you can see when using an eyepiece. It is measured in degrees – the higher the number, the wider the field of view. These views of the Moon show the FOV of three different eyepieces used with the same scope. The FOV is given in degrees (°) and arcminutes (′) above each view.

25mm eyepiece with a 650mm telescope

10mm eyepiece with a 650mm telescope

10mm eyepiece and 2x Barlow with a 650mm telescope

How to...

Record the Geminid meteor shower

With
Paul Abel

Graduate from casual shooting star observer to meteor-spotting citizen scientist

▲ **The further away a meteor appears from the radiant of the shower, the longer its trail will be**

PETE LAWRENCE, PAUL ABEL X 2, ISTOCK, JON HICKS

December's cold and frosty nights mark the arrival of the year's richest meteor showers: the Geminids. The shower runs from 8-17 December with peak activity occurring on the morning of 14 December. This year the Moon sets before 21:30 UT so the display won't be drowned in lunar glare. Here, we're going to look at why these observations are useful to researchers and how best to observe the Geminids and record them.

All meteor showers are produced by either a comet or an asteroid that we call the parental body. The Geminids are caused by 3200 Phaethon, an Apollo-type asteroid that orbits the Sun every 1.4 years. 3200 Phaethon has a rather eccentric orbit; the furthest it ever gets from the Sun is a distance of 2.4 AU (aphelion) but its closest distance (perihelion) is just 0.1AU – closer to the Sun than the planet Mercury. 3200 Phaethon has the distinction of being the only asteroid in the Solar System to get this close to the Sun!

While it's in the inner Solar System, heat from the Sun causes particles to escape from the surface of Phaethon and fly away into space. Eventually, these particles collide with Earth; they burn up as they hit the atmosphere, causing a glowing trail, or what we call a meteor or 'shooting star'.

Since Earth is colliding with a cloud of particles, the meteors appear to us to come from one direction in the sky; this is called the radiant and the location of the radiant gives the name of the shower. The radiant for meteors in the constellation of Gemini gives the shower its name: the Geminids.

Meteor showers are a good opportunity for astronomers to study their parental bodies, so amateur observations are

TOOLS AND **MATERIALS**

▶ The British Astronomical Association (BAA) meteor section report form – **www.britastro.org/pdf/MeteorSectionVisualReportBlank.pdf**

▶ A clipboard

▶ A red light

▶ A star atlas to identify the faintest star you can see

▶ Warm clothing! The Geminids are in December and so it will be cold

▶ A deckchair or sunlounger so you can comfortably sit back and look up at the sky

▶ An accurate clock to record the times of observations

▶ Food and a hot drink that will keep you going in the cold early hours

particularly welcomed by organisations such as the British Astronomical Association (BAA). If, for example, analysis of the observations reveals that the radiant has shifted, this could indicate orbital changes. We can also infer how active the parental object has been during its passage into the inner Solar System.

Make it a group activity

Useful observations of meteors require an organised meteor watch. You can look for meteors on your own, but it is common to observe in groups with one member acting as a recorder and filling in the form as the various observers call out their sightings. The report form used by the BAA is available electronically, so you can print it out and use it during your session.

Although the Geminids have a Zenithal Hourly Rate (ZHR) of over 100 meteors an hour, this number can be misleading since it assumes optimum viewing conditions: a radiant that's high in the sky and no light pollution or clouds. In reality you won't see as many as this. Geminids tend to be swift and usually white in colour – the streak they leave behind is called a meteor train and it may persist for a few seconds.

You'll need to record the names of all observers, your location and contact details along with the start and end times (in UT) of your session. You also need to make a note of the stellar limiting magnitude of your site by locating and identifying the faintest star you can see with the naked eye.

As the watch gets underway, you'll need to record the times the meteors were observed along with their estimated magnitude. Remember, not all of the meteors observed will be Geminids! A true Geminid will have either a short train close to the radiant or a longer one further away; it must also be moving away from the radiant. If your meteor is not obeying these rules it is what's known as a 'sporadic' and not part of the shower – you should still record it but label it 'sporadic'. You also need to include any constellations that the meteor passes and how long it takes to fade.

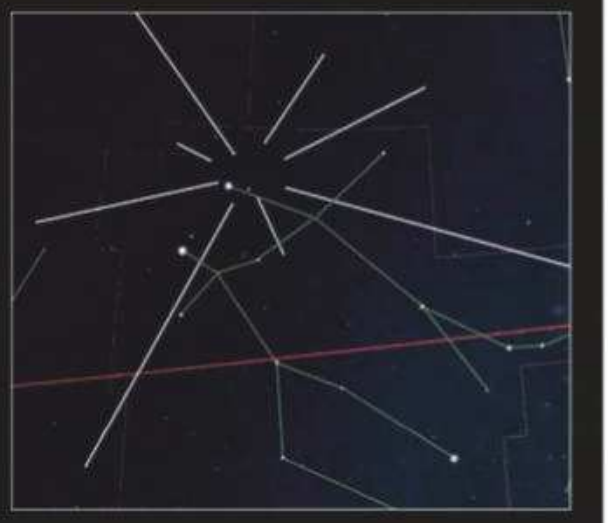
Once indoors, you should type your observations into the report form and save it on your computer so that you have a good permanent record. And don't just let the data you've collected sit around. Send your observations to the Meteor Section of the BAA – the scientists there will make good use of the data!

PAUL ABEL is co-host of *BBC Sky at Night Magazine*'s Virtual Planetarium

STEP BY STEP

STEP 1

Before you start, make sure you have a good view of Gemini all night. If you're observing in a group, work out who will record the observations. Set up your seating so you're facing the radiant and make sure you have plenty of observing forms.



STEP 2

Peak activity occurs on the morning of 14 December, so you'll need to be outside for about 22:30 UT onwards on the night of 13 December. Activity is likely to be low before midnight but as the radiant climbs higher in the sky, the count should increase.

STEP 3

Once outdoors your eyes need to become dark adapted; this usually takes about 20 minutes. If you're observing in a group, everyone needs to do this. One flash from a bright light can ruin your dark adaption, and it can take 15 to 20 minutes to recover.

Magnitude	Objects
– 4	Venus
– 2	Jupiter
– 1	Sirius
0	Capella, Rigel, Arcturus
+1	Regulus, Pollux
+2	Belt stars of Orion
+3	Delta (δ) Ursae Majoris
+4	Eta (η) Persei
+5	Faintest naked-eye meteors

STEP 4

Use a star atlas with a red light torch or planetarium software to identify the faintest star you can see with the naked eye. Record the magnitude of this star – this is your stellar limiting magnitude and indicates the faintest meteors you can detect.

STEP 5

Once the watch is underway, record the start time and use the report forms to record observations. If any of the meteors are notable, record why in the notes section of the form. For magnitude estimates of meteors, use the table provided above.

STEP 6

When you're done, record the time you finished along with the duration of the watch. Once home, it's a good idea to transfer your data onto the electronic report form as soon as possible. Then send your observations to the BAA.

Image PROCESSING

With
Stuart McIntyre

Producing a panorama using PTGui

Mastering the software that stitches together overlapping photos seamlessly

▲ **A panoramic view of the Three Sisters peaks in the county of Argyll, taken using multiple frames stitched together in PTGui**

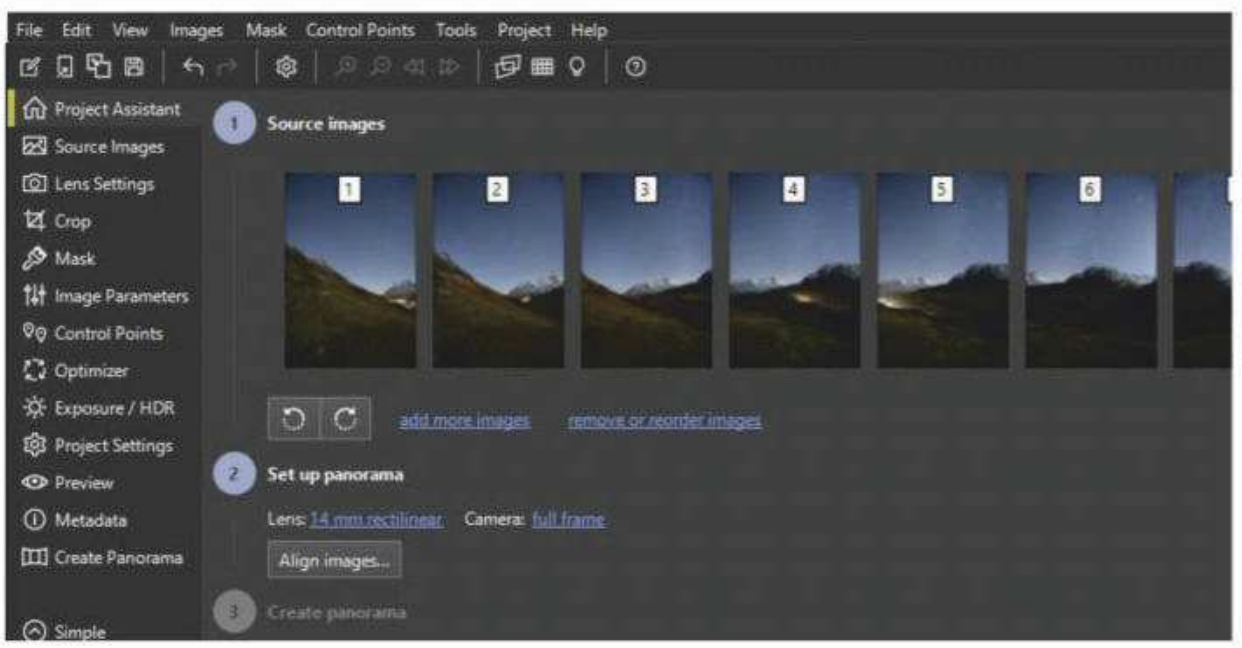
Most people think of astrophotography in terms of zooming in on tiny stars or galaxies. But I want to capture it all… literally. That's why I create multi-pane panoramas. In this article we look at how to piece together those panes.

Once you've captured your images (see page 38) you need to merge them with as few errors and aberrations as possible. One of the most reliable pieces of software to do this is PTGui, which we'll be using here.

First open your images in your preferred image editing software so that you can alter all the tones in every photograph to mid-range. Edit one photograph and then apply the same changes to all the other photographs. At this point we're not worried about making the images pretty; we're taking them to mid-tones so that PTGui can more easily match up their details. The principle is that you first create the panorama using the mid-tone images, then PTGui 'records' how it's achieved the stitching together so that it can do exactly the same to the 'real' photos.

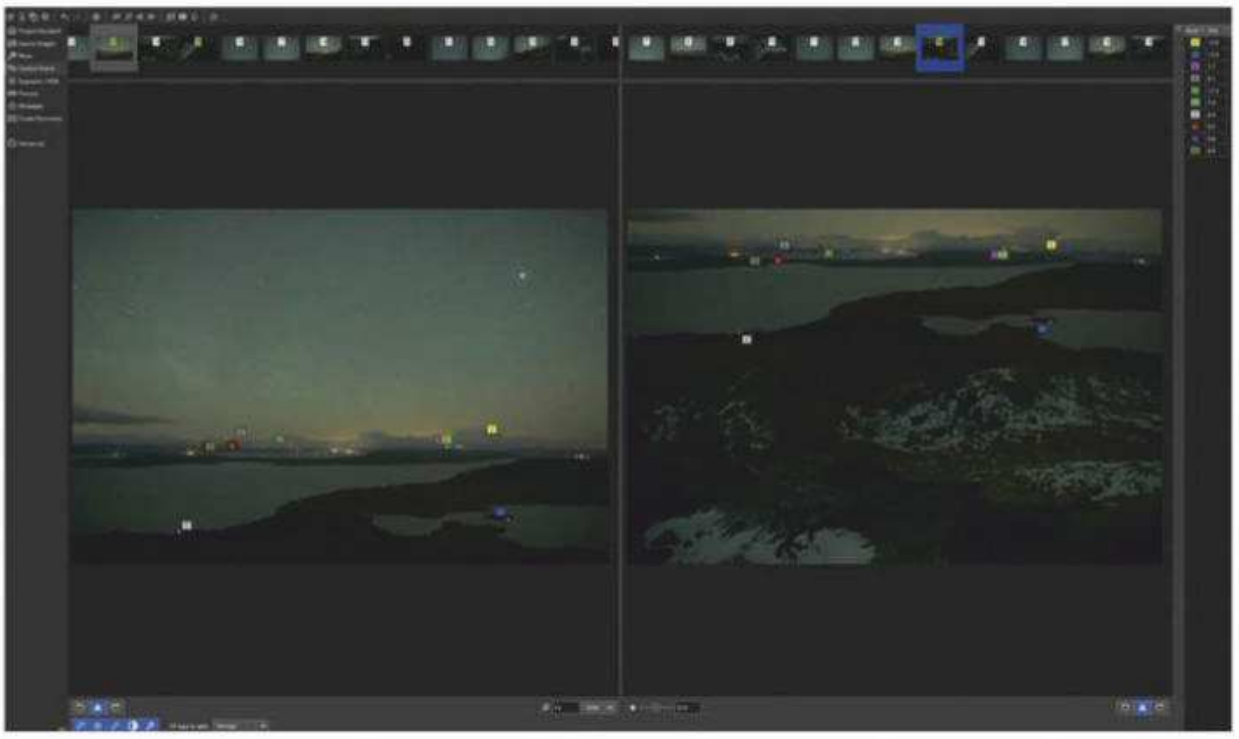
Export these mid-tone versions of the images with their meta data included so that PTGui can read the focal length used. Open PTGui and load in your mid-tone files using the Load Images button – the interface walks you through the process.

To the software stars all look pretty much the same, so it's unlikely that PTGui's automated stitching will be able to generate the final image without some help from you.



▲ **PTGui was originally designed as a Graphical User Interface for Panorama Tools, hence the name**

ALL PICTURES: STUART MCINTYRE



▲ Control points indicate the same features in different positions in different photos

▲ With negative masking you can 'paint out' things you don't want appearing in the final image

But press the Align Images button anyway and let the program have an attempt.

You have control

PTGui will probably be able to stitch together the foreground of the image but not the stars. In most cases it will report that there has been an error and invite you to review the 'control points'. Control points are areas in different source images that coincide, and should overlap in the panorama. PTGui generates control points automatically but not always accurately. Stars are difficult for PTGui to recognise.

Instead you need to manually create your own control points. Click on one image and then click on the same star in the neighbouring images; repeat this process with three or four more stars to get a good spread of stars around the image.

If you were lucky enough to capture a meteor in one image and you want to use it in the final panorama you can mask it to ensure that it's present in your final image. You do this by clicking on the Mask tab and selecting the Paint With Green option, then highlighting the detail you want to keep. You can also Paint With Red to hide details you don't want appearing in the finished product. The image below left shows this technique being applied to car lights.

Once all this is done go to the Project Assistant and press the Align Images button. This time you should hopefully be presented with a completed image in a tab named Panorama Editor. Look for errors in the image. Sections of 'double stars' (normally on one axis) or distorted areas are common. To rectify this, open the Control Point Assistant and look at the Control Point Table. The larger numbers indicate control points that are least accurate; replace them with more accurate control points.

When you're happy with the stitch of your image, it's time to make the photo look pretty. Take your original source photos into your preferred image editing software and get them looking how you want them. Export them, then go back into PTGui and go to the Source Images tab; right click on each image in the left-hand panel and select Replace, then click on the corresponding 'pretty' image from wherever it's saved on your computer. When you've replaced all the images you can click on Preview to see the stitched-together image.

At this point you can play around with different settings without fear of losing your work. At the bottom right-hand side of the window there are two sliders named Vertical and Horizontal Field of View. Leave the field of view wide and then crop the image later. Close the panorama editor.

Finally, export the image. It's probably huge so it's worth thinking about how you intend to use the image and how many pixels you really need, then scaling down your image to save your sanity. Finally select file type and press "Create Panorama".

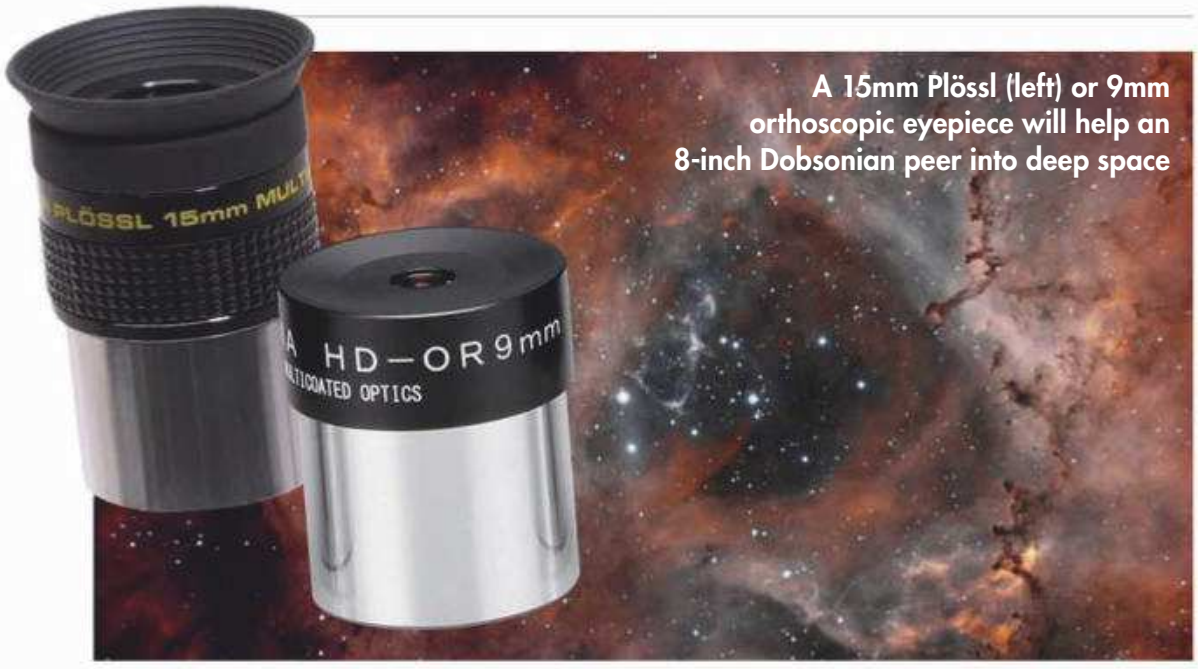
STUART MCINTYRE *is a professional photographer with a panorama passion*

▲ This is the Panorama Editor, in which you can manipulate your final stitched-together image

Scope DOCTOR

With **Steve Richards**

Our equipment specialist cures your optical ailments and technical maladies



A 15mm Plössl (left) or 9mm orthoscopic eyepiece will help an 8-inch Dobsonian peer into deep space

I have an 8-inch Dobsonian. What eyepieces and filters would you recommend for viewing nebulae and star clusters? (I have a K25mm, K12mm and 7.5mm Plössl.)

PETER LEWIS

Your telescope has a nominal focal length of 1,000mm giving it a relatively fast focal ratio of f/5, meaning it gathers a good deal of light.

Of the three eyepieces you mention you have in your collection, the K25mm and K12mm have the simple three-element design of a Kellner eyepiece which has a relatively narrow apparent field of view, although this may not be an issue for you when making lunar and planetary observations. However, Kellners work best in telescopes with a focal ratio of f/6 to f/8 or greater.

Plössl eyepieces are excellent for general use although their eye relief will diminish as the eyepiece's focal length reduces. This design is most suitable for observing nebulae and star clusters. A 15mm and 25mm Plössl eyepiece would be good additions to your current line-up.

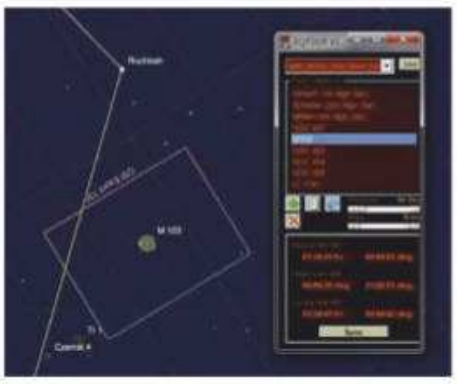
For lunar, planetary and double star observations, high magnification and reasonable eye relief (to make viewing as comfortable as possible) are prerequisites. An orthoscopic design is an excellent choice in this regard, giving slightly better eye relief than a Plössl with high contrast views. 4mm and 9mm versions would be a good match for your telescope.

A filter would also be a worthwhile purchase. They screw into the internal threads within the barrel of your eyepieces and help enhance the contrast of nebulae against the background. Popular choices are Ultra High Contrast (UHC) and OIII filters from Lumicon, Astronomik or Baader.

ISTOCK, STEVE RICHARDS

My new telescope is a Celestron CGX. Is it possible to download the magazine's Deep Sky Tour and import into my mount?

GRAEME DURDEN



▲ EQTOUR being used with planetarium software Carte Du Ciel

We produce an EQTOUR format data file each month to accompany the printed Deep Sky Tour (see page 5 for details). Unfortunately, this data cannot be imported directly into your Celestron CGX mount or indeed any other. However, both EQTOUR and your mount are ASCOM compatible. This means that you can control your mount using any ASCOM-compatible planetarium software like the free Cartes du Ciel and Stellarium, or paid-for programs like TheSky and Starry Night, and run EQTOUR at the same time.

Controlling your Celestron CGX mount using a laptop PC and a planetarium program is a fantastic way of locating objects to observe or image. As a bonus, you can then select each of the objects in that month's tour using EQTOUR and instruct the planetarium software to slew the mount to point at each object automatically.

You can connect your mount to a PC using a mini USB cable from the PC to the USB socket on the hand-controller.

STEVE'S TOP TIP

What is a baffle?

Astronomers strive to obtain the maximum contrast that their telescope and eyepieces will allow so that dim objects stand out better against the night sky. Light pollution spoils contrast but so too does stray light bouncing around inside the telescope tube.

Baffles are frequently built into many telescope designs to stop this unwanted light from reaching the eyepiece by stopping it in its tracks. A baffle is a ring made of thin plastic or aluminium that is attached to the inside of the optical tube and is painted in a black matt finish to further absorb unwanted light. It is common for there to be several such baffles within the tube.

STEVE RICHARDS is a keen astro imager and an astronomy equipment expert

Email your queries to scopedoctor@skyatnightmagazine.com

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BBC Sky at Night MAGAZINE

Reviews

Bringing you the best in equipment and accessories each month, as reviewed by our team of astro experts

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding
★★★★★ Very good
★★★★★ Good
★★★★★ Average
★★★★★ Poor/Avoid

90
If you're planning on replacing your beginner's binoculars we have six suggestions that'll increase your observing power at a very reasonable cost

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Find out more about how we review equipment at **www.skyatnightmagazine.com/scoring-categories**

6 of the best

WORDS: STEVE TONKIN

10x50 binoculars, £100-£200

Light but with apertures ample enough to observe many faint objects, these all offer a significant quality hike over budget offerings

Helios Stellar II

Price £159 • **Weight** 1,190g **Extras** • Wide, neoprene neck strap; tethered objective caps and rain-guard; robust, lightly padded fabric case • **Supplier** Optical Vision Ltd • **Tel** 01359 244200 **www.**opticalvision.co.uk

The Helios Stellar II binoculars are the only ones in this test that have individual eyepiece focusing. This is the preferred option for astronomy, meaning you can set the focus and then leave it alone. These are also the heaviest pair, which means that they are the most likely to tire your arms, although we did find that their mass also helps to reduce shake.

We were impressed with the brightness and excellent colour rendition of the image, which is sharp over the central 80 per cent of the 6.5° field of view. This makes them ideal for scanning the sky.

They have several useful features, including tethered lens caps for the objective lenses and the eyepieces. By having these caps attached to the binoculars, they won't get lost and you're probably more likely to use them, too. They are covered in a substantial, ribbed rubber armour that offers protection against everyday knocks, and gives a secure grip even when the binoculars are damp from dew.

VERDICT

If you want 10x50s specifically for astronomy, these would be a very good choice
FOR Bright images, good colour rendition, wide field
AGAINST Relatively heavy
OVERALL SCORE ★★★★★

Opticron Imagic TGA WP

Price £179 • **Weight** 935g • **Extras** Wide, nylon neck strap; tethered objective caps and rain-guard; semi-rigid vinyl case **Supplier** Opticron UK • **Tel** 01528 726522 • **www.**opticron.co.uk

The Opticron TGA binoculars are more than 100g lighter than any of the other Porro prism binoculars in this test group, but this doesn't come at the expense of ruggedness. Not only are they covered in a substantial rubber armour, but they come with a semi-rigid case that offers excellent protection against the rigours of regular, varied use.

Their field of view is on the narrow side at 5.3°, but this is compensated for by extremely good colour correction and colour rendition. Star colours were vibrant in the eyepieces. Images were bright and stars were tack-sharp across the middle 75 per cent of the field of view. We thoroughly enjoyed scanning colourful star-fields with these.

They are very well-balanced, which makes them feel even lighter than they actually are. This means you can use them for long periods before aches and strains set in. The ribbing on the prism housing gives a very secure grip, even if they are damp with dew.

VERDICT

A very versatile, lightweight all-rounder, which is also useful for astronomy
FOR Excellent colour rendition; lightest Porro on test
AGAINST Relatively narrow field of view
OVERALL SCORE ★★★★★

Nikon Action EX

Price £179 • **Weight** 1,069g • **Extras** Wide, nylon strap with soft anti-slip neck patch; tethered rain-guard, tetherable objective caps; lightly padded fabric case • **Supplier** Wex • **Tel** 01603 486413 • **www.**wexphotovideo.com

From the moment you take these binoculars out of their lightly padded case, they ooze quality. They have a robust feel in the hand and everything – hinge, focusing, twist-up eye-cups – works smoothly with just the right amount of stiffness to prevent accidental readjustment. The eyepiece rain-guard is tethered, and the objective caps can be secured to the binoculars' strap to prevent you mislaying them.

They are just as impressive under the stars, which snap to focus anywhere in the central 85 per cent of its 6.5° field of view, giving a bright, crisp, high-contrast image. Colour rendition and control of false colour are both very good. There is just enough eye relief for spectacle-wearers to be able to see the entire field of view. They are well-balanced and hence relatively easy to hold steady, and the chunky lugs on the right eyepiece dioptre make adjustments easy, even when you're wearing thick gloves. The rubber armour stops them from becoming slippery when wet with dew.

VERDICT

Very capable general-purpose binoculars that are good for both day and night-time use
FOR Bright, good colour; wide flat field
AGAINST Heaviest centre-focus binocular
OVERALL SCORE ★★★★★

Vortex Crossfire

Price £179 • **Weight** 924g • **Extras** Wide, padded neck strap; tethered objective caps and rain-guard; lightly-padded fabric case
Supplier First Light Optics • **Tel** 01392 791000 • **www.**firstlightoptics.com

The Vortex Crossfire is a good example of how modern manufacturing processes have narrowed the gap in optical quality between Porro and roof prism binoculars of similar prices. The 6.1° field of view is on a par with the Porros and flat enough that we could keep Albireo split into two components over the central 90 per cent. Colour rendition was excellent; not only do the deeply coloured stars seem vibrant, but the subtle differences between similarly coloured ones are easily visible as well.

The focus is smooth and precise and the short-hinge design leaves more room for your fingers, making these binoculars very comfortable to hold. There is enough eye-relief to allow you to observe while wearing spectacles. The objective lens caps are tethered to the screw in the adaptor bush in the hinge, so they become untethered if you mount the binoculars. Apart from that, the only other niggle is the high minimum interpupillary distance (IPD: 60.5mm), which is an inevitable feature of the roof prism design used for 50mm aperture.

VERDICT

If you want a compact but capable and versatile 10x50, this could be ideal for you
FOR Bright, sharp views, superb colour; lifetime guarantee
AGAINST Large minimum IPD
OVERALL SCORE ★★★★★

Celestron Outland X

Price £129 • **Weight** 790g • **Extras** Narrow, nylon neck strap; tethered objective caps and rain guard; lightly padded fabric case
Supplier David Hinds Ltd • **Tel** 01525 852696 • **www.**celestron.uk.com

Weighing just shy of 800g, these are easily the lightest binoculars on test. We found them very comfortable to handle and enjoyed the sharp on-axis views they gave. Colour correction was quite good, as was the colour rendition – it was easy to distinguish the orange of Herschel's Garnet Star (Mu (μ) Cephei) from the brilliant white of Alderamin (Alpha (α) Cephei) and the yellow of Zeta (ζ) Cephei.

The eye relief is a very short 10mm, and some of this is taken up by the recess of the eye lens. Consequently, we were unable to see the entire field of view when we tried observing while wearing spectacles.

They are specified as being 'multi-coated' and, although the anti-reflective coatings on the lenses were effective, the image was noticeably dimmer than with the other binoculars in this test, all of which were specified as 'fully multi-coated'. In common with most 50mm roof prism binoculars, the minimum interpupillary distance is limited by the design and is relatively large at 61mm.

VERDICT

Okay if you want some lightweight, general-purpose binoculars for occasional astronomical use
FOR Good colour rendition, lightweight
AGAINST Inadequate eye relief, large minimum IPD
OVERALL SCORE ★★★★★

Pentax SP WP

Price £159 • **Weight** 1,060g • **Extras** Wide nylon strap with soft neck patch, untethered caps and rain-guard, lightly padded, strapless fabric case • **Supplier** 365Astronomy • **Tel** 02033 845187 • **www.**365astronomy.com

The Pentax SP series of Porro prism binoculars is characterised by an unusual focusing mechanism. Gone is the familiar eyepiece bridge, because all the workings are internal, aiding with waterproofing. It also allows them to incorporate an enormously useful feature: focus locking. This is achieved by sliding the centre-focus band along its spindle. Another helpful design feature is the inclusion of large lugs on the right eyepiece dioptre, which make it easy to adjust even with thick gloves.

The first thing you notice about the image these binoculars produce is how much of it is very sharp: the two components of Albireo only merged in the outside 10 per cent of the field of view. However, this field of view is only 5°, the narrowest of all the binoculars we tested. Colour rendition is faithful, and on-axis chromatic aberration is very well controlled; false colour only appeared on the lunar limb towards the edge of the field. The minimum interpupillary distance of 52mm makes these binoculars suitable for people with small faces or close-set eyes.

VERDICT

Optically and mechanically very good, these binoculars will suit a wide range of people
FOR Sharp image, locking focus
AGAINST Narrow FOV; ill-fitting, untethered lens caps
OVERALL SCORE ★★★★★

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FIRST **LIGHT**

See an interactive 360° model of this scope at **www.skyatnightmagazine.com/cel114lcm**

Celestron 114LCM computerised telescope

WORDS: PAUL MONEY

A great starter scope with which to begin your adventures in astronomy

VITAL STATS

- **Price** £349
- **Optics** 114mm Newtonian telescope
- **Focal length** 1,000mm, f/9
- **Mount** Motorised altazimuth
- **Tracking rates** Sidereal, solar and lunar
- **Hand controller** NexStar computerised hand controller with 4,000-object database
- **Power** 8xAA batteries or 12V DC 750 mA
- **Extras** StarPointer red dot finder, 25mm and 9mm 1.25-inch fit eyepieces
- **Weight** 5kg (OTA 2kg)
- **Supplier** David Hinds Ltd
- **Tel** 01525 852696
- **www.**celestron.uk.com

With modern optics and computerisation, today's starter telescopes are a far cry from the scopes many of us began our astronomy adventures with. Celestron's 114LCM Computerised Telescope, for example, combines reasonable optics with a computerised mount to give beginners a tantalising taste of what there is to see in the cosmos.

The 114LCM consists of an optical tube with a 4.5-inch mirror and a focal length of 1,000mm giving a focal ratio of f/9. It has a basic rack and pinion focuser that takes 1.25-inch eyepieces: 25mm and 9mm eyepieces are provided giving magnifications of 40x and 111x. A built-in StarPointer red dot finder helps to aim the telescope, especially during the alignment phase. The tube is attached to the motorised base via a Vixen-style mounting bar that connects to the aluminium tripod using a bolt on the underside. It's quick and straightforward to assemble as there are just three main sections: tube, base and tripod. The 114LCM comes with a NexStar hand controller that has a database of 4,000 objects from the main deep-sky databases (Messier, NGC and Caldwell). Also included are the Solar System, variable stars and double stars. Power is provided by eight AA batteries that sit in a built-in compartment. aAlternatively you can use a power tank providing 12V 750mA.

SKY SAYS...
A reasonable viewing and imaging platform for beginners

Ducks and dumbbells

The 114LCM has five alignment modes. We tested them all and in each case achieved the best alignment and tracking using Celestron's bespoke SkyAlign system. Solar System Align is also useful for daytime alignment, especially if the Moon is up. Using the 25mm eyepiece we checked the quality of the field of view by targeting Altair (Alpha (α) Aquilae). The star was pin sharp across 75 per cent of the view with a little coma towards the field edge. The view through the 25mm eyepiece is big enough to fit in all of the Moon and more – we estimate it has a field of view of just over 1.25°.

Using the Sky Tour option we explored a wide range of targets. M11, the Wild Duck Cluster, was ▸

Height and weight

The first thing you'll notice about the LCM114 is how light the complete package of telescope, motorised base and tripod is. Weighing a total of just 5kg, it's ideal for young beginners to assemble and set up (with guidance from an adult). The height is also convenient for youngsters – with the optical tube aligned horizontally, the eyepiece sits 83cm high when the tripod legs are at their shortest and only 122cm high at their longest. With the telescope aligned vertically, the eyepiece is just 4cm higher at both points so even objects at the enith are easily accessible. The fully extended height puts the eyepiece in a comfortable position for adults. The tube on its own is only 2kg – two bags of sugar – making it easy to lift onto the motorised base. We could lift the whole fully assembled system up and quickly take it outside for a quick look at the stars, which makes this a good grab-and-go computerised system that can be run on batteries.

ALL PICTURES: WWW.THESECRETSTUDIO.NET

Optics

The LCM114 has a 4.5-inch primary mirror with a focal length of 1,000mm, which gives you a focal ratio of f/9. For its size, it offers good views with pin-sharp stars across almost three quarters of the field of vision in the supplied 25mm eyepiece.

Focuser and finder

The basic focuser uses a rack and pinion design and accepts 1.25-inch eyepieces. It was a little loose initially, but tightening the two screws underneath removed any play. The StarPointer is a red dot finder built into the system. It gives zero magnification but helps you focus in on your target.

Tripod and accessories tray

The telescope stands on three lightweight aluminium telescopic legs that can be clamped using the integral locks to raise/lower the assembly. The accessories tray locks the legs in place and provides somewhere to place the eyepieces during use. The tripod was reasonably stable, although breezes did shake the view a little.

Motorised base

The mount holds the electronics and gears for altaz operation and houses a battery compartment for eight AA batteries, a 12V power socket and a clutch for the altitude adjustment/tensioning. The mounting clamp allows the optical tube to be attached via the Vixen-style dovetail bar, holding it securely in place.

FIRST LIGHT

SKY SAYS...
Now add these:

1. Celestron 7Ah powertank

2. Celestron eyepiece and filter kit

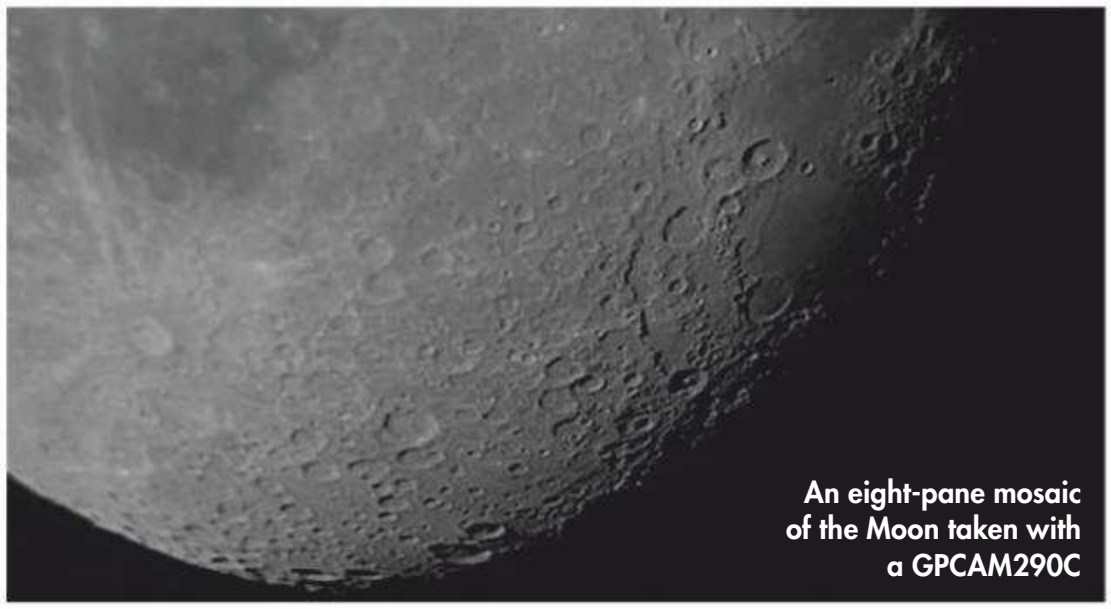
3. SkyPortal Wi-Fi module

▸ a hazy patch with a bright star and a smattering of almost-resolved stars around it, especially when we swapped to the 9mm eyepiece for more magnification. The Dumbbell Nebula, M27 – a planetary nebula – was quite bright and mottled while M57, the Ring Nebula, was a ghostly hoop of smoke hanging in space. Albireo (Beta (β) Cygni), the late-summer/early-autumn showstopper, is a double star and with the 114LCM its gold and sky-blue components were clearly separated and very colourful.

Andromeda was rising in the east during the test period so we took in M31, the Andromeda Galaxy. It's a large object so with the 25mm eyepiece we could see the inner core and just get its companion, M32, in the view by slightly offsetting from the centre. The fainter satellite galaxy, M110, was not easy but could be spotted with averted vison. M45, the Pleiades star cluster, filled the view of the 25mm eyepiece with stars while the Orion Nebula, M42/43, was awash with nebulosity.

Although it's not designed as an imaging system, we used the 114LCM with our webcam to see what results were possible. Deep-sky imaging is not possible but we did capture a shot of Saturn and its rings, as well as producing an eight-pane mosaic of the Moon, which was very satisfying. We also captured a poor image of the Moon using an iPhone. The low quality was partly down to a damaged adaptor, but it shows there's potential with this set-up.

The view while focusing can be a little shaky, but you can lessen the effect by making small adjustments to the focuser. There's no denying this telescope has a plasticky feel but this helps keep its cost down. My own astronomy adventure began with a 60mm refractor but I wish this scope had been available back then, as it whets the appetite, and that's what a beginner's telescope is all about. S



An eight-pane mosaic of the Moon taken with a GPCAM290C

◂ GPCAM290C webcam image of Alberio, made up of a stack of 1,000 frames

Hand controller

The NexStar+ LCM hand controller lets you control, align and operate the telescope. It has a database of 4,000 targets including Solar System, Messier, NGC and Caldwell objects, along with double stars, variable stars and more. It has lots of utilities to get the most out of the system.

Verdict

Assembly	★★★★½
Build and design	★★★★½
Ease of use	★★★★½
Features	★★★★½
Optics	★★★½☆
OVERALL	★★★★½

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FIRST **LIGHT**

See an interactive 360° model of this camera at **www.skyatnightmagazine.com/bressar-80/640**

Bresser Messier AR-80/640

Nano refractor

WORDS: STEVE RICHARDS

Portable and easy to use, the Nano offers everything a new stargazer needs

VITAL STATS

- **Price** £169
- **Optics** 3-inch achromatic refractor
- **Focal Length** 640mm, f/8
- **Mount** Twilight Nano altaz
- **Extras** Red dot finder, 26mm Plössl eyepiece, 1.25-inch star diagonal, smartphone camera mount, T2 adaptor ring, planetarium software, instructions, planisphere
- **Weight** 5kg
- **Supplier** Telescope House
- **Tel** 01342 837098
- **www.**telescopehouse.com

The Bresser Messier AR-80/640 Nano is a complete beginner's telescope. It's a 3-inch achromatic refractor that's bundled with everything a newcomer needs to get started: a manual altaz mount, a red dot finder, a star diagonal and a 26mm Plössl eyepiece. Its 3-inch aperture is more than adequate to allow observations of a wide range of celestial objects, its altaz mount is intuitive to use and the whole thing is a doddle to set up.

Achromatic doublet lenses, like the ones in this scope, are made from two types of glass that work together to minimise chromatic aberrations – an unwanted effect that produces coloured halos around bright objects. More expensive optics have a number of special coatings applied to reduce reflections and increase light throughput, but this lens assembly has only one coating of magnesium fluoride (MgF_2) – the minimum required.

The inside of the seamless aluminium optical tube is nicely blackened, though and has a single baffle to help reduce unwanted internal reflections. A substantial, non-retracting, aluminium dew shield (also with a nicely blackened interior) cuts down on unwanted light entering the telescope, as well as doing an excellent job of keeping dew at bay.

SKY SAYS...
Affordable, portable and very capable the Nano is a great scope to start stargazing with

Externally, the optical tube is finished in high-gloss white with Bresser's trademark red pinstripe around the base of the dew shield. The optical tube is clamped in a plastic clamshell mounting ring, which attaches to an aluminium Vixen-style dovetail bar. The dovetail bar has been drilled and tapped to take both 1/4-20 and 3/8-16 tripod mounting bolts, so it can be used with other mounts, while the scope's aluminium construction keeps the weight down, making it highly portable.

A complete package

The left side of the plastic focuser housing has an inverted T-slot for mounting the supplied red dot finder. The finder has adjustable brightness and makes locating bright celestial objects very easy.

The complete system comes almost fully assembled and, to further assist in any beginner's first forays into observing, it's supplied with Stellarium planetarium software on a CD and a waterproof planisphere to help locate suitable ▸

Simple-to-use mount

The AR-80/640 Nano's altaz mount is simple to use as it has no control knobs to adjust. The mount consists of a single arm that's slightly offset towards the right and to the rear. It holds the telescope in such a way as to prevent it from clashing with the tripod's legs when you point it at the zenith.

What, at first sight, appears to be the adjustment handle of a pan-and-tilt head, is actually a convenient rod for moving the telescope both in azimuth and altitude. The telescope's position is maintained by the friction of the two axes although we found that the vertical axis was too tight and had to make a small adjustment to slacken it off and make it usable.

The AR-80/640 Nano's mount incorporates a standard Vixen-style dovetail clamp with a single locking bolt. Conveniently, the supplied dovetail bar has a small recess for the locking bolt that serves as a catch should the bolt come loose.

ALL PICTURES: WWW.THESECRETSTUDIO.NET

Eyepiece

The telescope is supplied with a 26mm Plössl eyepiece with filter thread providing 25x magnification. This eyepiece is perfectly adequate for a beginner but the unusually deep recess to the top lens element meant that even with the rubber eyecup folded down, the eyepiece was unsuitable for observing while wearing spectacles.

Smartphone holder

A lightweight smartphone holder is included, which attaches to the eyepiece tube with a collar and thumbscrew. A smartphone is then strapped to the holder with an elastic strap and held over the lens of the eyepiece by a series of rubber suction pads.

Rack and pinion focuser

A very simple, single-speed, straight-cut rack and pinion focuser is provided with the telescope. Although this design can result in the eyepiece 'nodding' when you're changing focus direction, this particular example was surprisingly solid and stable. There is a thumb screw on the top of the focuser to add tension if required.

Tripod

The steel and plastic tripod is lightweight but adequately stable for this size of telescope and mount – especially so in its retracted state with the plastic leg spreader in use. The stainless steel legs are 1.25-inches in diameter and provide height adjustment from 80-124cm (measured at the centre of the telescope tube).

FIRST **LIGHT**

iPhone 5S image using the AR-80/640 Nano's smartphone adaptor and 26mm eyepiece

SKY SAYS...
Now add these:

1. Bresser PL 10mm eyepiece 31.7mm/1.25-inch

2. Revelation Astro 2x Barlow lens

3. Explore Scientific Filter Set 1 – Moon and planets 50mm

▸ objects to observe. Construction-wise, the emphasis is on lightweight materials throughout, making it a good 'grab and go' instrument to encourage beginners to leave the city lights and head for a dark observing site.

Observations

We used the AR-80/640 Nano to observe a range of objects, a couple of which have been tricky to see from our fixed observatory location this year because they've been too low on our tree-lined southern horizon. But the AR-80/640 Nano scope is so light and hassle-free that it allowed us to observe both Mars and Saturn simply by moving the whole setup to suitable positions in the garden. We located the two planets using the 26mm eyepiece supplied, clearly observing Saturn's rings, then enjoyed more close-up views using 8mm and 5mm eyepieces.

Views of the Moon were also very good with only a tiny amount of chromatic aberration visible on the limb. We then turned to deep-sky objects and observed M13, M92, M31, Albireo, Vega, the Double Cluster, M103, M45 and finally Orion, in the early morning. We used Vega as our optical test star and found excellent star shapes out to just over 80 per cent of the field of view using the 26mm eyepiece.

The setup includes an eyepiece mounting for a smartphone and we used this to capture some images of the Moon using an Apple iPhone 5S, the 26mm eyepiece and the volume control button on our headphones as a shutter release. The individual images were then stacked in AutoStakkert! to produce a final image that any beginner would be delighted with. We did, however, find that the elastic retaining strap that was supposed to hold the smartphone in place had a tendency to slide off the mount's oval surface.

Overall, however, we were very pleasantly surprised at how well the Bresser Messier AR-80/640 Nano performed and would certainly recommend it to astronomy newcomers or anyone looking for a lightweight, easy-to-set-up telescope to supplement a more advanced system. S

Red dot finder

A basic red dot finder is provided with the AR-80/640 Nano for locating celestial objects. It helps you locate bright objects such as stars by projecting an apparent red dot on the sky. Moving the telescope until the star and dot are aligned with each other automatically aligns the telescope with the object.

Verdict

Assembly	★★★★☆
Build and design	★★★★☆
Ease of use	★★★★☆
Features	★★★★☆
Optics	★★★★☆
OVERALL	★★★★★

WWW.THESECRETSTUDIO.NET, STEVE RICHARDS

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Books

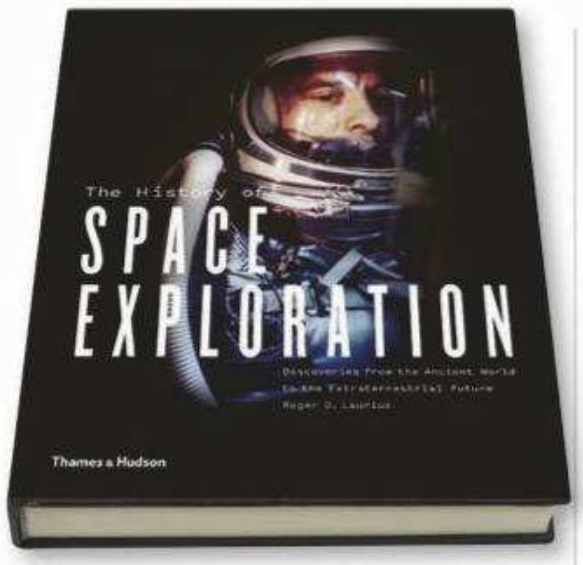
New astronomy and space titles reviewed

RATINGS

★★★★★ Outstanding
★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

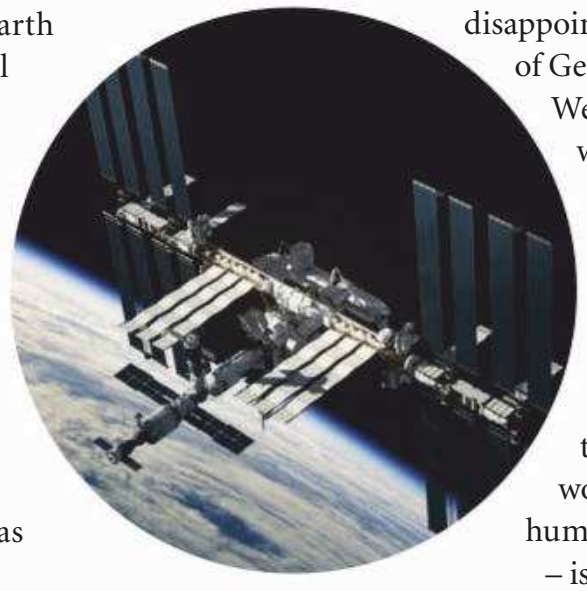
The History of Space Exploration: Discoveries from the Ancient World to the Extraterrestrial Future

Roger D Launius
Thames & Hudson
£24.95 ● HB



"Rockets are cool," says SpaceX founder Elon Musk. "There's no getting around that." Yet, as this comprehensive history of space exploration shows, it's been a hard-won combination of imagination, bravery and ingenuity that's brought us to permanent human habitation of space even if, for the moment, that's no farther than the relatively low Earth orbit of the International Space Station.

Author Roger D Launius, chief historian of NASA from 1990 to 2002, has produced an informed and informative read that never talks down to its reader. While not necessarily as definitive as that titular 'The' might suggest – not least because Launius's final chapter on future missions is necessarily speculative – it's no mere hagiography of NASA's achievements. The book's sixth chapter in particular provides a succinct introduction to the expanding 'space club' of nations, from the Cold War formation of the European Space Agency in 1964 to the more contemporary space achievements of India, Japan and China. And did you know that Argentina is developing its own satellite-launching rockets, expected to make their first flights in 2019?



Mankind is currently confined to low Earth orbit on the ISS

Launius presents some uncomfortable truths with surprisingly little comment. Of the significant progress in rocketry made in the run-up to – and during – the Second World War, he blandly states that, "every belligerent nation developed some type of rocket technology as a weapon." Some readers may also be disappointed that the legacy of German rocket pioneer Wernher von Braun – who "created both a weapon responsible for the deaths of literally thousands of people, and a launch vehicle that would give rise to the rockets that would eventually take humanity into space" – is described merely as "mixed".

Broken up into easily digestible two- or three-page chunks and with a clean, uncluttered design, the result is a book you can either dip into or settle down for a longer perusal. Heavy to hold, perhaps, but not a heavy read.

★★★★☆

PAUL F COCKBURN *is an astronomy and science journalist*

ISTOCK

TWO MINUTES WITH Roger D Launius

When does the history of space exploration begin?
One could say it began with the first successful rockets, and if anyone wants to date it from Sputnik 1 in 1957 I would not argue. I tend to push the beginning back to the time of the Scientific Revolution. When humans first realised that some of those points of light in the night sky might be planets they also began thinking about how they might visit them. The process of getting there required centuries more before realisation.

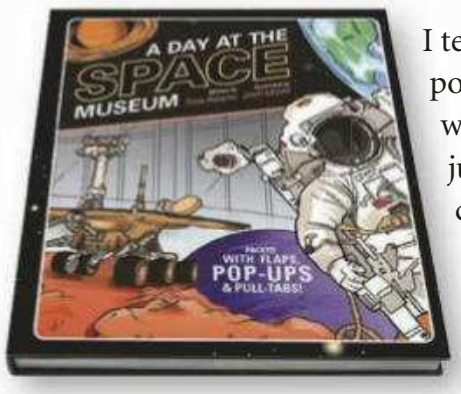
Which of the rocket-powered missions are your favourites?
Beyond Apollo, I am endlessly amazed by the voyages of discovery to the outer Solar System. Pioneers 10 and 11, Voyagers 1 and 2, Galileo, the Cassini Huygens mission to Saturn, cometary missions and New Horizons to Pluto and the Kuiper Belt are all fascinating and have rewritten our understanding of the Solar System and its place in the cosmos.

What are your hopes for the future of space travel?
Humans may be able to return to the Moon and establish a permanent presence there. The next most likely goal would be a coalition of nations to pursue human exploration of the Solar System: asteroids and the moons of Jupiter and Saturn, for example. The most obvious target would be Mars. Because of the cost, technology and risk it seems unlikely any one nation would undertake an expedition to Mars. An international endeavour spreads the risk, cost and difficulty.

ROGER D LAUNIUS *was NASA's chief historian from 1990 – 2002*

A Day at the Space Museum

Tom Adams, Josh Lewis
Templar Publishing
£14.99 ● HB



I tend to approach pop-up books with caution, not just because they can be rather fragile, but also because the pop-up feature can sometimes be little more than a gimmick. But with *A Day at the Space Museum* that's not the case. The pop-ups and pull tabs genuinely teach you about space in various fun and ingenious ways.

The book has seven very colourful pop-up spreads illustrated by Josh Lewis, covering topics such as the Solar System, cosmic explosions, the Milky Way and other galaxies, supernovae, nebulae, black holes, a history of space travel and living on Mars. The bold illustrations are very clear, and I can personally verify that the mechanics of the 3D structures are sturdy enough to withstand the attention of a two-year-old!

As you would expect with a pop-up book, with very thick, multi-layered pages the total amount of content is relatively limited compared to its thickness, but the book uses the space wisely. There are sections that fold out to reveal the Universe in a range of scales, and mini-books about important figures in astronomy. Meanwhile, little rotating wheels demonstrate the phases of the Moon or the stages of terraforming required to make Mars habitable.

The content is largely approachable for a younger reader (perhaps a keen eight- to 10-year-old), though slightly older readers might find some of the concepts more accessible. One pet peeve is the statement that we see "the Sun through the day and the Moon at night", which is frustrating given that it's on the page about phases of the Moon and the geometry of eclipses.

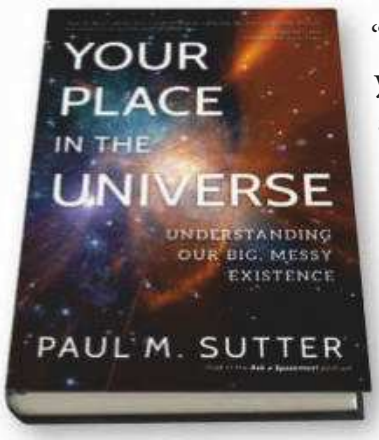
Overall, this is very well-designed book that will keep its audience interested as they explore the 'space museum'.

★★★★★

DR CHRIS NORTH *is Odgen Science Lecturer and STFC Public Engagement Fellow at Cardiff University*

Your Place in the Universe:
Understanding Our Big, Messy Existence

Paul M Sutter
Prometheus Books
£18.99 ● HB



"How the heck do you write a book about the whole entire Universe?" These are the words that greet you when you open the first pages of Paul M Sutter's *Your Place in the Universe*. The book takes you through the past 400 years of astronomy, touching on the stories of the great scientists who pieced together the modern picture we have of the cosmos.

You'll read about the early ideas we had about our Universe; how evidence has slowly shaped and changed those ideas over and over again; and how the Universe may ultimately end.

Sutter admits upfront that he pays attention to the stories and physics that have captured his attention the most. And why not? It's his book! Even so, it remains fairly comprehensive and Sutter touches on all the major highlights.

The prose is a little hard going at times; for me it was a little too conversational. In places, I had to reread sections and I found ideas and concepts jumped about a little. I'd hesitate giving this book to someone new to cosmology; I felt I kept up with it in places because I knew the underlying story.

However, I really enjoyed the more personal side of the scientists that Paul reveals, and I applaud the lack of equations. Extra points for all the wonderful references in the back: it's a fantastic collection of some of the most important papers in this field. If you're a cosmology enthusiast, definitely give this book a go.

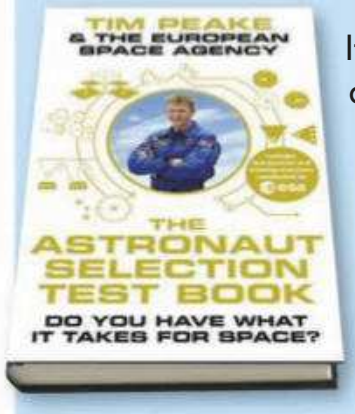
★★★★☆

LAURA NUTTALL *is a senior lecturer in gravitational waves in the Institute of Cosmology and Gravitation at the University of Portsmouth*

The Astronaut Test Selection Book

BOOK OF THE MONTH

Tim Peake, ESA
Century
£20 ● HB



If you want to apply to be an astronaut you may need this 'not for dummies' guide. You'll be in superb hands: Tim Peake has been there, seen it, done it and now wears the ESA spacesuit.

It's a brain work-out on steroids, stuffed with authentic selection tests covering language skills, maths, science, engineering, communication and psychology. Buckle up and aim high! You'll 'sweat the small stuff' – an astronaut mantra – with fiendish exercises. Tackled individually or as a group, they'll leave you feeling confident, crushed, confounded or enlightened. But it's fun!

Entertaining and engaging, this intelligent book is educational and for the serious-minded. Are you a decisive team player? Do you have the necessary 'competencies' and 'behavioural markers' to get you closer to space? These tasks will find you out and help get you there. At the very least, they will deepen your understanding of life in zero-G.

By revealing Peake's own experiences, we're shown what's required of a would-be astronaut, and why. You will come to know your own strengths and weaknesses. You will get things wrong. There may be no 'right'. Regular 'debriefs' explain all.

Crucially, *The Astronaut Selection Test Book* is innovative, earnest, soulful and exhilarating; a route to the stars but also a road map for any career application. It's a guide for life itself, on Earth, the ISS, Mars or anywhere.

★★★★★

JANE GREEN *is author of the* Haynes Astronomy Manual

Gear

Elizabeth Pearson rounds up the latest astronomical accessories

1 Celestron PowerTank Lithium Pro

Price £239 • **Supplier** Harrison Telescope 01322 403407 • www.harrisontelescopes.co.uk

This 20x15x10cm powertank will keep your electronics charged for up to 17 hours. Lightweight and with multiple ports, it's a great power source for remote observing trips.

2 Heated body warmer

Price £104.99 • **Supplier** Sports Bike Shop 01205 360099 • www.sportsbikeshop.co.uk

With three heated panels covering your chest and lower back, this toasty vest will keep you warm throughout the night. Requires an external battery pack.

3 T2 female dust cap for M42x0.75

Price £4.95 • **Supplier** Northern Optics 01724 782022 • www.northernoptics.co.uk

Keep the dust out of your optics using these screw caps. Designed to fit the standard M42x0.75 thread used on most T-adaptors, Barlow lenses and focusers.

4 Farpoint 2-inch desiccant cap

Price £48.60 • **Supplier** 365astronomy 020 3384 5187 • www.365astronomy.com

Fill the cap with desiccant sachets, then slide it into the drawtube of your scope to keep your optics moisture free during storage.

5 Meteorite necklace

Price £35 • **Supplier** MSG meteorites msg-meteorites.co.uk

Carry a shooting star with you wherever you go. This necklace contains a slice of meteorite that's been specially treated to bring out the beautiful Widmanstätten pattern.

6 Coast red-white clip light

Price £15.99 • **Supplier** ITS 020 8532 5000 • www.its.co.uk

Clip this LED torch onto clothing, tents or your bag to keep your hands free. Provides both white and red light, and is impact and weather resistant. Runs on two AAA batteries.

WHAT I REALLY WANT TO KNOW IS...
What does Mars smell like?

Stephen Lewis is sniffing Mars's atmosphere for clues about life, climate change and weather conditions for future landings

INTERVIEWED BY SHAONI BHATTACHARYA

Mars is a good example of a planet we think has undergone drastic climate change in its early days. It is presently a cold desert, but in winter there are large weather systems very similar in scale to those we experience in the UK. The intriguing question is: while Mars is currently very cold and dry, could it have been warmer and wetter in the past? Certainly, there's evidence in the rocks on the surface that it was. So was it ever habitable? Could it have even been – in the distant past, four billion years ago or so – a place where life could have started?

My role involves monitoring and understanding the current state of the atmosphere on Mars but also looking for tiny traces of gases that may reveal something about Mars's past using the Trace Gas Orbiter (TGO) to 'sniff' them out.

The TGO was launched in March 2016 and arrived at the Red Planet in November 2016. There were no observations until it got into its science orbit in late spring of this year. We are now getting science data on a regular basis.

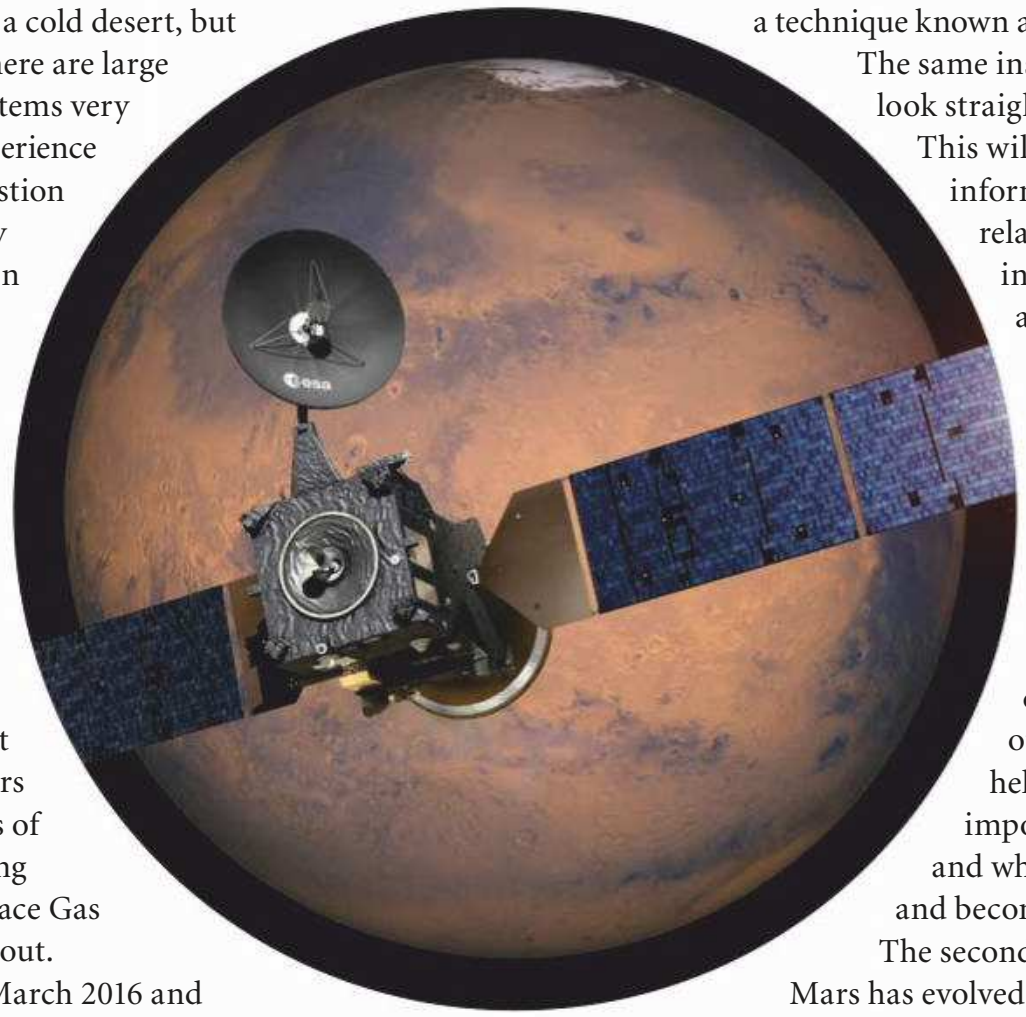
We know that the bulk of the atmosphere is carbon dioxide, nitrogen and a few noble gases, but what we really want to know is are there any other trace gases that don't fit in with the equilibrium gases that possibly give a hint of something that's happening on Mars today, or long, long ago?

A very useful heat haze

We are looking down to parts per billion; it takes some very sensitive spectroscopy to find gases that are such tiny components of the atmosphere. So to give us a better chance of finding them, the spacecraft will also be looking as the Sun rises and sets through the Martian atmosphere.

Why? Well, currently TGO is about 400km above the surface, orbiting every couple of hours. In every orbit it sees one sunrise and one sunset. For a brief few minutes as the Sun sets or rises, the TGO will, because of its angle, be looking at it through a long stretch of Mars's atmosphere; that gives you a large sample for spectroscopy and a greater chance of detecting even minor gases in the atmosphere. This is a technique known as limb sounding.

The same instruments used for this will look straight down at the planet as well. This will give us another source of information because the surface is relatively warm and gives off infrared radiation that will be absorbed and re-emitted by gases in the atmosphere as it rises up towards to the TGO.



ESA/DAVID DUCROS

The Trace Gas Orbiter will be using sunsets and sunrises to have a really good look for anomalous gasses in Mars's atmosphere

Life lessons

Why are we doing this? One reason is so that we can test our models of Earth's climate systems. It might change our ideas about how our own atmosphere works or help us understand what's important about Earth's climate, and what causes climates to change and become less habitable.

The second reason is learning how Mars has evolved and asking if Mars were ever a habitable place, which opens up some huge questions. Just because life could evolve somewhere, does it always evolve? Or is life still incredibly unlikely? We have only one example: Earth. Was that just an incredible fluke?

Of course, you can't actually smell Mars – if you took your helmet off you'd die fairly quickly. But thinking about what it might smell like is a way speculating about what Mars's atmosphere might be made up from. The main gases, including carbon dioxide and nitrogen, don't smell of anything. But we are trying to look for tiny trace amounts of out-of-balance gases. We are not directly smelling them, but looking at their spectra.

Essentially, there would be a sort of rusty smell that you'd get from the dust of oxidised rocks. The other smell might be a methane-farty smell – to put it crudely – if there were bacterial or microbial life on Mars. Methane is one of the trace gases we are looking for, but its presence wouldn't necessarily prove the presence of life, now or ever. It could have come from a totally non-living process, like geothermal activity.

ABOUT PROFESSOR STEPHEN LEWIS

Professor Stephen Lewis is a professor of atmospheric physics in the school of physical sciences at the Open University. He is co-investigator for the NOMAD instrument aboard the Trace Gas Orbiter craft currently orbiting Mars

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The Explore Scientific Achromatic Doublet Refractors

AR 102mm f/6.5 £517
AR 127mm f/6.5 £588
AR 152mm f/6.5 £713

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Explore Triplet Apo Refractors

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127mm Essential Version £1330

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THE SOUTHERN HEMISPHERE IN DECEMBER

With Glenn Dawes

WHEN TO USE THIS CHART

1 DEC AT 24:00 AEDT (13.00 UT)
15 DEC AT 24:00 AEDT (13.00 UT)
31 DEC AT 23:00 AEDT (12.00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

DECEMBER HIGHLIGHTS

Comet 46P/Wirtanen makes its closest approach to the Sun and Earth this month, possibly reaching 4th magnitude. Best viewed in the late evening it starts the month high in Cetus and heads north, roughly following the border between Cetus and Eridanus. On 15-17 December it passes between the Hyades and Pleiades star clusters in Taurus, when it is expected to be at its brightest. Wirtanen moves quickly into Auriga, and on 23 December will be just 1° from the bright star Capella.

STARS AND CONSTELLATIONS

One of the longest and faintest constellations, Eridanus, the River, is visible in the evening sky. Its headwater is the mag. +2.8 Cursa (Beta (β) Eridani), near Rigel in Orion. Consisting of around two dozen 4th to 5th magnitude stars, the River snakes its way south, ending at one of the most isolated 1st magnitude stars, Achernar (Alpha (α) Eridani), near the Small Magellanic Cloud. Eridanus resides in deep-sky heaven, as the area is the home of numerous galaxies.

THE PLANETS

Saturn is low in the evening twilight early in December. Look for the thin crescent Moon nearby on 9 December. With the ringed planet's exit, Mars is prominent in the northwest, setting around midnight. Neptune and Uranus are also visible, departing in the early morning. The action then switches to brilliant Venus rising in the predawn, followed by Mercury well down in the dawn glow. Jupiter returns to the morning, passing Mercury on 22 December when they will be only 0.8° apart.

DEEP-SKY OBJECTS

In northern Eridanus you'll find the naked-eye mag. +2.9 star Zaurak (Gamma (α) Eridani) at RA 3hr 58.0m, Dec. –13° 31'. This star is rare, being one of the brightest known red giants (class M0). Binoculars will assist in seeing any orange-red colouration.

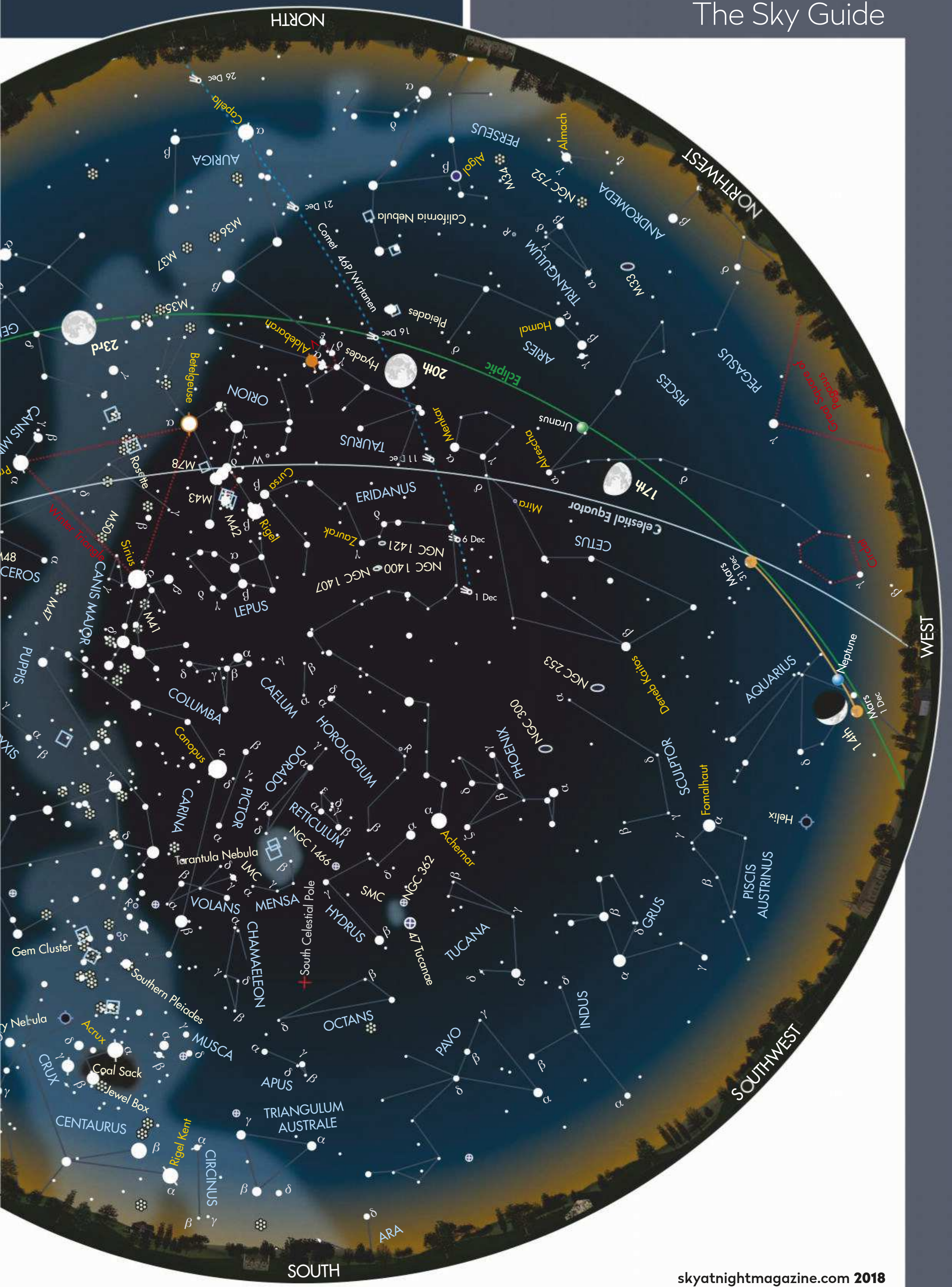
A short hop 3.7° west, you'll find the edge-on spiral galaxy NGC 1421 (pictured) at RA 3hr 42.5m, Dec. –13° 29'. Although only mag. +11.4, it makes a rather pleasing white streak, with an obvious halo around a short, pencil-line core. Move 5° south to enjoy two spiral galaxies in the same field, NGC 1400 and 1407. Separated by only 12 arcminutes, both exhibit bright stellar nuclei surrounded by obvious halos. NGC 1407 is the slightly larger and the slightly brighter of the two (mag. +9.7 vs mag. +11.0).

CHART KEY

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE, IMAGE: THE CARNEGIE-IRVINE GALAXY SURVEY (CGS)


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
26 Dec
21 Dec
16 Dec
11 Dec
6 Dec
1 Dec
31 Dec
1 Dec
Capella
Algol
Almach
PERSEUS
ANDROMEDA
NGC 752
M34
California Nebula
Comet 46P/Wirtanen
TRIANGULUM
M33
M36
M37
M35
Pleiades
Hamal
ARIES
Alcyone
Hyades
Aldebaran
Ecliptic
20h
23rd
Betelgeuse
ORION
PISCES
PEGASUS
Great Square of Pegasus
Uranus
Alrescha
Meinkar
TAURUS
11 Dec
17h
Celestial Equator
M78
Rosette
Cursa
M43
M42
Rigel
Sirius
Winter Triangle
ERIDANUS
Zaurak
NGC 1421
NGC 1400
NGC 1407
Mira
CETUS
Mars
31 Dec
Circlet
CANIS MAJOR
M50
M48
M47
M41
LEPUS
PUPPIS
COLUMBA
CAELUM
HOROLOGIUM
NGC 253
Deneb Kaitos
AQUARIUS
Neptune
Mars
1 Dec
1 Jan
Canopus
CARINA
PICTOR
DORADO
RETICULUM
NGC 1466
PHOENIX
NGC 300
SCULPTOR
Fomalhaut
Helix
Achernar
Tarantula Nebula
LMC
SMC
NGC 362
47 Tucanae
VOLANS
MENSA
HYDRUS
TUCANA
GRUS
PISCIS AUSTRINUS
CHAMAELEON
South Celestial Pole
Gem Cluster
Southern Pleiades
OCTANS
INDUS
PAVO
MUSCA
Acrux
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Performance, Precision and Value

Sky-Watcher is a First-Class telescope brand offering an incredible range of high-quality astronomical telescopes and accessories, catering for users of all age groups and abilities, from the novice right up to the serious advanced astronomer. Sky-Watcher astronomical telescopes perfectly integrate modern optical technology with precision mechanical engineering, resulting in designs of suberb functionality, versatility and uncompromising levels of performance.

EXPLORER-130 & EXPLORER-130M 130mm (5.1") F/900 NEWTONIAN REFLECTOR TELESCOPES

- Magnifications (with optics supplied): x36, x72, x90, x180 • Highest Practical Power (Potential): x260 • Diameter of Primary Mirror: 130mm
- Telescope Focal Length: 900mm (f/6.92) • Eyepieces Supplied (1.25"): 10mm & 25mm • x2 Barlow Lens • 30% more Light Gathering than 114mm
- R.A. Motor Drive With Multi-Speed Handset (Explorer-130M only) • Red Dot Finder • EQ2 Equatorial Mount • Aluminium Tripod with Accessory Tray

Sky at Night GROUP TEST WINNER

Explorer-130 Model

EXPLORER-130
(Without R.A. Motor Drive)
Prod.Code 10922

SRP £189

EXPLORER-130M
(With R.A. Motor Drive)
Prod.Code 10713

SRP £229

Explorer-130M Model illustrated

"Every class of object we viewed could be seen clearly… Taking everything into account, this telescope made observing the night sky enjoyable… great views coupled with ease of use."
BBC Sky at Night Magazine

PARABOLIC REFLECTORS – PREMIUM FEATURES

Both the SKYHAWK-1145P & EXPLORER-130P models below offer excellent all-round performance on The Moon, Planets & Deep Sky Objects. They feature premium quality Parabolic Primary Mirrors to eliminate spherical aberrations, producing even sharper, higher-contrast images which are full of detail. A "Paraboloidal" mirror is ground to a complex shape which brings all incoming light rays to a perfect focus, on axis. In addition they feature 0.5mm Ultra-Thin secondary mirror supports, to reduce diffraction spikes and light loss.

SKYHAWK-1145P 114mm (4.5") F/500 PARABOLIC NEWTONIAN REFLECTOR TELESCOPE

- Magnifications (with optics supplied): x20, x40, x50, x100
- Highest Practical Power (Potential): x228
- Diameter of Primary Mirror: 114mm
- Telescope Focal Length: 500mm (f/5)
- Eyepieces Supplied (1.25"): 10mm & 25mm
- x2 Barlow Lens • Parabolic Primary Mirror
- 0.5mm Ultra-Thin Secondary Mirror Supports
- Red Dot Finder
- EQ1 Equatorial Mount
- Aluminium Tripod with Accessory Tray
- 125% more Light Gathering than 76mm

Prod.Code 10709

SRP £159

Sky at Night GROUP TEST WINNER

"The optics were so good... Captures star clusters and brighter nebulae beautifully... The planet (Saturn) was jaw-droppingly beautiful, with a host of fine detail visible... The review instrument certainly delivered in every important respect."
BBC Sky at Night Magazine

EXPLORER-130P 130mm (5.1") F/650 PARABOLIC NEWTONIAN REFLECTOR TELESCOPE

- Magnifications (with optics supplied): x26 & x65
- Highest Practical Power (Potential): x260
- Diameter of Primary Mirror: 130mm
- Telescope Focal Length: 650mm (f/5)
- Eyepieces Supplied (1.25"): 10mm & 25mm
- Parabolic Primary Mirror
- 0.5mm Ultra-Thin Secondary Mirror Supports
- Red Dot Finder • EQ2 Equatorial Mount
- Aluminium Tripod with Accessory Tray
- 30% more Light Gathering than 114mm

Astronomy HOT Product

Prod.Code 10712

SRP £229

"I was most impressed by the views revealed by the 'scope during tests… Despite a phase of nearly 96 percent, the waxing gibbous Moon revealed a seemingly inexhaustible amount of fine detail... Highly recommended!"
Astronomy Now Magazine

76 page Full Colour Catalogue

COMPREHENSIVE COLOUR CATALOGUE with Full Details of our EXTENSIVE PRODUCT RANGE as well as Helpful Information & Advice

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Sir Patrick Moore Endorsed Sky-Watcher Telescopes

"I have used a great number of telescopes; some are good, some mediocre and some bad. To me the Sky-Watcher range of instruments are very good indeed, & suited to amateurs of all kinds - and they are not priced out of the market! Excellent value. Use them and enjoy them."
Sir Patrick Moore CBE FRS (1923-2012)

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